SCS
NATIONAL
ENGINEERING
HANDBOOK

SECTION 19

CONSTRUCTION INSPECTION

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SOIL CONSERVATION SERVICE
UNITED STATES DEPARTMENT OF AGRICULTURE

NATIONAL ENGINEERING HANDBOOK

SECTION 19

CONSTRUCTION

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CHAPTER 1. INTRODUCTION

Purpose

The purpose of this handbook is to provide for uniformity in the inspection of construction improvements and to aid in the determination of and compliance with technical provisions of the contracts. Guidance is also provided for making construction surveys and delineation of construction work. Each construction employee should become familiar with the material presented herein so that he may better understand the requirements for inspection, testing and documentation of contract work. The handbook should prove especially helpful to new or inexperienced personnel in training for assignment to construction staffs. The handbook is intended as a reference on matters not coming within the actual scope of the specifications and should be used as a guide in providing engineering services for all contract construction projects.

It is also intended that many of the procedures may be applied to the construction phase of other programs administered by the Service.

Scope

The scope of this handbook is limited to inspection of work undertaken by formal construction contracts, equipment rental contracts and by force account. Inspection requirements and procedures relating to specific phases of construction have been included in detail. Procedures for making field tests, forms for recording field test data and other required record forms are included. Where instructions contained herein are found to be in conflict with contract provisions, or state policy, the terms of the contract and the directives of the state will prevail.

Terminology

Definition of Terms

Wherever the words herein defined occur in this handbook or in the contract documents, they will have the following meaning, except as the context of the specifications may indicate otherwise:

Contract.--The written agreement between the contractor and the buyer of the contractor's services, setting forth the terms and conditions under which the work is to be performed or materials are to be furnished. It includes all of the contract documents.

Contracting organization.--The designated sponsoring organization including federal, state or others authorized by law to enter into formal contract for the installation of works of improvement.

Contracting officer.--The individual designated to enter into and administer contracts and to make determinations and findings with respect thereto; the term includes the contracting officer's representative acting within the limits of his authority.

Engineering services.--The technical services required for satisfactory installation of the project; to be performed by the responsible party as mutually agreed to in the Project Agreement or Engineering Services Agreement.

The required services to include layout, testing, on-site inspection and specified records and reports.

The responsible party may include: personnel employed by the Service; employees of the Contracting Organization; or A and E firms under contract to the Service or to the Contracting Organization.

Contractor.--Party of the second part to the contract, acting directly or through an authorized lawful agent or employee.

Drawings.--The drawings, or reproductions thereof, which show the location, and the detailed design of the contemplated work included in the contract.

Specifications.--A written or printed description of work to be done, forming a part of the contract and describing methods for measurement and payment, qualities of material and mode or tolerance for construction procedures, including special directions or other information not shown on the drawings.

Government representative.--The individual designated by the Service to carry out its obligations, protect its interest and maintain close working relations with the contracting local organization. He performs or directs the performance of inspections and related reports required by the Service. He verifies the progress of works, interprets drawings and specifications and recommends acceptance of work.

Project engineer (Engineer).--An engineer designated by the Service for assistance on a specific project or projects. He may serve as or assist the Government representative.

Inspector.--An inspector is assigned to construction job to determine day by day that the contractor complies with the requirements of the contract. He keeps records of the work accomplished and the factors affecting its progress and quality. He is responsible to the Government representative.

Bid item.--A specified class, kind or location of work on which definite prices are set forth in the contract.

Work (the work).--The materials and operations necessary for the construction of the specific improvements as indicated on the drawings or set forth elsewhere in the contract.

Contract price.--Either the unit prices or lump sum amounts named for bid items in the contract.

Abbreviations

The following list includes the names and abbreviations for associations, societies, institutes, technical organizations and others which may be mentioned in the handbook or in the contract documents.

A.A.S.H.O.--The American Association of State Highway Officials.

A.C.I.--The American Concrete Institute.

A.G.C.--The Associated General Contractors of America, Inc.

A.I.S.C.--The American Institute of Steel Construction.

A.S.T.M.--The American Society for Testing Materials.

A.W.W.A.--The American Water Works Association.

C.R.S.I.--Concrete Reinforcing Steel Institute.

A.W.S.--American Welding Society.

A.S.A.--American Standards Association.

A.G.M.A.--American Gear Manufacturer's Association.

A.W.P.A.--American Wood Preserver's Association.

A.I.--Asphalt Institute.

B of R.--U. S. Dept. of Interior - Bureau of Reclamation.

F.S.--Federal Specifications.

Mil. S.-- Military Specifications.

H.I.--Hydraulic Institute.

A.A.--Aluminum Association.

N.E.M.A.--National Electrical Manufacturing Association.

N.E.C.--National Electrical Code.

P.C.A.--Portland Cement Association.

C.S.--Commercial Standards.

A.S.--American Standards.

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CHAPTER 2. CONSTRUCTION SURVEYS

Survey Equipment and Procedure

General.
The initiation and construction of large projects, including PL-566 watershed projects, require detail surveys. These surveys fall into two categories (1) design and (2) construction.

Surveys for design purposes, which includes the collection of preliminary and investigative information, and detail location survey data are reflected in the drawings and specifications. This phase of the survey program is outside the scope of this manual. However, it is important to stress the need for preparing a complete and comprehensible outline for making the design surveys, including limits of accuracy and methods all established in conformance with Service standards. This procedure is desirable so that controls and identifying information included in the drawings will be compatible with the information and data collected at the time the construction layout surveys are made. Errors and omissions in the drawings, revealed at the time of construction layout, often can be traced to insufficient and inaccurate design survey information. It is also important that adequate and properly referenced and identified monuments, transit points, B.M.'s, etc. be established in the field at the time the design surveys are made, so that the construction layout party will not experience difficulty and loss of time in establishing the planned lines and grades for the proposed construction.

It is good procedure to establish all of the major vertical and horizontal controls and structure limits for a new project prior to showing the site to prospective bidders. Such practice provides invaluable information to the bidders and also permits the construction force to establish key points for construction control well in advance of contract operations. Any appreciable errors or omissions in the drawings substantiated by the construction layout should be brought to the attention of the State Conservation Engineer.

Survey Equipment.
The Government Representative is responsible for seeing that adequate kinds of surveying equipment are available for staking all construction operations on the job. He is also responsible for determining that the equipment is of a quality that will maintain the accuracy required. State offices should be advised of the needs for survey equipment on construction projects well in advance of the time required for use. Each man should handle and use all survey equipment with the same care

as if he owned it personally. Members of the survey party must be warned to take extra precaution to protect all survey equipment while working on construction projects. Equipment operators cannot be expected to safeguard the surveyor's equipment.

Vehicles used to transport survey equipment should be equipped with adequate boxes, tubes and tie downs to safely segregate and protect all instruments, rods, tripods, range poles and other survey equipment.

All surveying equipment, especially instruments, rods and tapes, should be checked frequently to determine that each item is accurate and serviceable.

Notebooks and Notekeeping

Field Notebooks.
Bound field notebooks should be used for watershed projects or other contract work where the notes might be used as evidence or supporting data in case of disputes. Duplicating bound field notebooks are preferred. When duplicating field books are used, the book containing the duplicate notes can be left on the job at all times for use by the construction inspector or survey party. The original sets of notes should be removed daily and properly filed in the construction office for safe keeping.

Numbering notebooks.--Notebooks used to record construction notes for watershed works of improvement should be numbered in a separate series for each structure; except that notes for a group of small structures may be placed in the same notebook provided they are included in the same contract. The number of field construction notebooks required will depend on the organization and size of the project. It is desirable to limit the number of books to the minimum required for efficient operations.

Place the name of the watershed and the structure site number(s) on the outside face of each notebook. Place in the top right corner of the outside front face of each book, "Book No. ____ of ____." Fill in consecutive book number as each book is added to the job. Fill in total number of books at end of project. In all cases the identifying name and number(s) should be lettered with India ink or other products equally permanent.

Identifying notebooks.--Identify all field notebooks so that they can be returned to proper headquarters if lost. Place this identification on the inside of the front cover or on the flyleaf of the bound notebooks.

The following identification is suggested:

U. S. GOVERNMENT PROPERTY

Finder please return to
SOIL CONSERVATION SERVICE

____
(Street or P.O. Box No.)

____
(City) (State)

It may be desirable to have stamps prepared with the above wording.

Numbering pages.--The two faces of an open field notebook constitute a single page. Number the pages of each bound field notebook consecutively. Insert the page number in the upper right-hand corner of the right-hand page.

Indexing surveys.--Sufficient pages in the front of each bound notebook should be reserved for indexing the notes contained in the book. Each survey title and the page number for the initial page of the survey should be recorded in the index section.

Note identification.--Show the following information at the top of the right face of the first page of notes for each survey: (Refer to example field notes Figs. 2-16, 2-21, 2-23, and 2-24.)

Top right corner

Page number

Date

Names of party members and assignments

Weather

Left of center line

Title or purpose of survey (bench mark levels, embankment cross sections).

Repeat title on all pages required for the survey.

Do not repeat other items in heading unless there is a change in party members or date.

Recording.--Record all numbers, figures, and explanatory notes clearly and in sufficient detail so that they will be legible to anyone who needs the information. Use pencils in the hardness range of 3H to 5H. Do not erase numbers. If an error is made in recording a number, draw

a line through it and write the correct number above or to one side. No notes of any kind should ever be erased or destroyed. If notes taken are to be voided, they should be crossed out by drawing diagonal lines across the page and writing void across it in such a manner that the notes will still be legible. All field notes should be recorded in the notebook as the survey work progresses. Entries of field notes taken on loose paper or in memorandum books are not acceptable.

There is a tendency on the part of some field engineers to make field notes too brief. Often the notes are kept in such a poorly arranged manner that it is difficult to interpret the full and correct meaning even though all the information may be shown. Good field notes should be so complete, logically arranged, and neatly recorded that the correct and complete meaning is readily grasped by any qualified technician.

The recorded data should give a true picture of the precision of the survey. The decimal point should never be omitted when recording decimals. When measurements are made to the nearest 0.01 foot, two digits should be recorded to the right of the decimal point even though the last one or two digits may be zero, for example, 2.10 or 4.00. Refer to Engineering Memorandum SCS-39 for further notekeeping details. The methods shown in this memorandum should be used for recording all field survey data.

Sketches.--Sketches or drawings are an important part of survey notes, and should be made for all situations that might not be clearly understood by one unacquainted with the site. Sketches should be included in the body of the notes in proper sequence to support the recorded note data. Sketches are rarely made to scale, but may be purposely exaggerated for the purpose of improving clarity. In some cases, reference can be made in the field notes to certain drawings or details in the contract drawings that will take the place of sketches.

Stationing.--The use of negative stationing is not desirable for any survey. This is especially true for surveys from which water surface profiles are computed by machine methods. Furthermore, the limits of the project design is not always known at the start of the survey. Therefore, the use of an initial station value greater than zero is recommended procedure. For these reasons, the station at the starting point for a construction project will often have a value greater than 0+00.

Right and left designation.--Banks of streams are conventionally designated right and left as viewed when looking downstream. Reference to topographical features, cross sections and slope stake notes should always be labeled right and left as viewed in the direction of increasing stations along the center line or survey control line.

Filing.

All original field notes and other construction survey data for a project installed by SCS engineering services should be forwarded to the State office for filing at the completion of the project.

Any duplicate copies of the construction survey notes should be transmitted to the Local Contracting Organization, accompanying copies of the "As Built" drawings.

The custody of the original construction survey notes for projects installed by the Contracting Local Organization's engineers should be in accordance with the provisions of the construction working agreement with the Service. If the agreement permits the local organization to retain the original notes, made available to the Service upon request, any duplicate copies of the notes should, at the close of the project, be transmitted to the State Conservationist with copies of the "As Built" drawings.

Construction Layout

General.
The moral effect of prompt service and accurate work in setting stakes cannot be overestimated. The contractor has the same right to demand service and accuracy from the engineer as the contracting agency has to demand that he fulfill the terms of his contract. The Government Representative should ascertain that construction stakes are set sufficiently ahead of the construction crew for the contractor to plan his work. Failure to establish the necessary stakes in a timely manner is inexcusable, and is a legitimate reason for the contractor to request an extension of time.

The Government Representative should inspect the drawings and the project with the contractor and discuss the proposed system of staking. In case the contractor determines that the suggested staking procedure will not be adequate for the proper guidance of his foremen, additional stakes should be set, unless terms of the contract prohibit the degree of staking requested.

The Government Representative, unless otherwise notified, is directly responsible for the construction surveys, and the marks and stakes set. Regardless of how the survey parties are organized administratively, the Government Representative must have full knowledge of the methods used and results accomplished. The work must be planned and executed with due regard for setting subsequent stakes or resetting lost stakes. The Government Representative should advise the contractor how to interpret the marks on the stakes and make no deviation from that method unless he informs the contractor in writing.

Prior to setting any construction stakes, the Government Representative, the Survey Party Chief, and the Inspector should make a thorough study of the plans in the office, and on the project with the plans in hand, so that complete understanding is reached as to the staking procedures.

Errors can seldom be corrected or changes made in procedure after the work starts, except at an increase in construction cost and time.

Established monuments and bench marks used as the origin of surveys for setting the initial lines and grades must be verified by re-run

and back-check to known monuments and bench marks. In case the design survey party has not established adequate bench marks, the construction survey party must establish new benches near all structures, and at such other locations as required for quick and ready access. At least two bench marks shall be set near each major structure in order that each leveling operation pertaining to the structure may be referenced to at least two points of known elevation.

All grade elevations shown in the drawings should be checked before any grade or slope stakes are set. While computing grade elevations for the stations shown in the drawings, elevations should also be computed for any additional stations or structure locations whose elevations must be known before setting construction stakes. All of this information must be carefully checked, and should be recorded on a grade computation sheet, or in the field survey notebook for convenient reference.

Permanent Monuments.
Adequate permanent markers should be set on, or referenced to, the centerline or some identifiable reference line for each proposed major structure. The centerline for embankments and channels is commonly used as a reference line for such structures. Permanent markers should be constructed of a convex brass or bronze cap embedded in concrete or a steel pipe or rod with suitable cap, firmly driven into the ground. The elevation of the marker should be stamped on the cap and it should be marked with a cross to denote the exact point monumented. Not less than two monuments should be set to establish a reference line from which all elements of the structure can be established. The description, location, elevation and any other pertinent information pertaining to each permanent marker should be recorded on the "As Built" drawings. When it is found that any section, subdivision, property corner or other survey monument is to be destroyed or buried by reason of project construction, the responsible agency should be notified. When requested by the agency, the monument should be referenced, the reference points to be at least as permanent as the corner destroyed or buried. Notes of all such references should be furnished to the appropriate authorities for filing and recording. All such references should be shown on the "As Built" drawings.

Referencing Lines.
All transit points necessary for the control of the work should be adequately referenced to facilitate quick re-establishment of any points which may be disturbed during construction.

Insofar as practical, reference points should be so situated that straight line measurement can be made between the reference point and the transit point.

All measurements should be made to hundredths of a foot. Hub locations that will be covered over or excavated so that the elevation of the ground at the point will be materially changed, should be referenced to four points so situated that the two lines connecting the diagonally-opposite points will intersect at the hub. One of the points on each reference line must be of a nature, and so located, that it can be

occupied by a transit. Establishment of the reference points or the re-establishment of the hub may be done by intersecting transit lines and can be checked by horizontal measurements along each respective line.

A section in the field notebook may be set aside for recording reference tie data in addition to the notes taken on the alignment survey. This data should show the station of each hub, the distance and approximate direction to each reference point, and a description of each reference hub. A sketch with orientation arrow should be included.

Stakes.

Stakes used for construction layout usually consist of wooden 1" x 2", 2" x 2" or both in lengths suitable for the proposed usage and the existing soil conditions.

The 2" x 2" stakes are commonly used for transit hubs, reference points or temporary bench marks, and may be from 9" to 18" in length. The 1" x 2" stakes may be used for center line, slope reference, grade or guard stakes and are usually 12 to 18 inches in length. Similar material 6 to 9 inches long may be used for flush grade reference in conjunction with the longer slope or grade stakes. Standard four-foot lath are often used to flag R-O-W, clearing limits or to reference other stakes. Nails or spikes may be used in lieu of wooden stakes for location or centerline stations where alignment follow old roads, streets or in rocky terrain. Large spikes make good permanent transit points and are often used in lieu of wooden hubs.

Staking Procedure.

Re-establishment of centerline.--The first field work should be that of checking the alignment with the plans, establishing new hubs which may be required, referencing hubs and checking topography. The centerline stationing may be established as the alignment is checked.

In those cases where the line to be constructed differs from the line originally staked because of alignment revisions made during design, the new line should be established in connection with the re-establishment of adjacent portions of the original centerline. Care should be exercised to insure that the relationship between the original and the revised line is maintained and that accurate ties are made to the original line. Equations in stationing should be checked and plainly recorded in the field notes and on the "As Built" plans.

Stakes for full stations and intermediate stakes are driven on the centerline with the station number marked on the side facing the initial station of the survey. Adequate centerline stakes should be set to record all breaks that affect measurement of quantities. Profile levels should be run and checked against the elevations shown on the drawings.

All transverse and longitudinal measurements, such as those made in setting stakes for centerline, right-of-way, clearing, slope and in taking cross sections should be measured horizontally. Centerline hubs

should be established at all structure locations, P. C. and P. T. of all curves, and at such locations on tangent as required for good vision and accessibility. These hubs should be driven flush and tacked. Guard stakes with stationing and other appropriate identification should be placed at each hub. Hubs that will be disturbed by construction operations should be referenced. After the centerline has been established and before any clearing or grubbing has been started, all topographical features which must be removed should be checked in the field. The distance to fences which parallel or intersect the centerline or any other portion of the structure, as well as the lengths of fence to be removed, should be recorded. Trees or other obstructions to be removed should be checked and recorded.

Right-of-way and clearing limits.--Right-of-way and clearing limits should be established from the staked centerline, or by other surveys as required to conform with the drawings. For dams, the right-of-way limits may be designated by closed traverse, while clearing limits may be specified by contour elevation. Service employees must bear in mind there are administrative limitations regarding the establishment of property boundaries. The local contracting organization is responsible for setting the basic control monuments for all right-of-way limits. The Service will establish only temporary stakes indicating limits to be used for administration of the construction contract. Clearing limits should be marked by use of paint brushed or sprayed on trees or by stakes (use a predetermined color) or flagging tied to existing vegetation spaced at about 100 feet, or more frequent intervals when necessary for good visibility. Where brush or timber is heavy, grade and slope stakes normally are not set, or the original cross sections taken until the required clearing has been completed.

However, if there are deep ditches or ravines in the embankment foundation area which may become filled with trash and top soil during the clearing operation, cross sections may be required before clearing operations start to insure that the foundation areas are satisfactorily stripped for construction.

Excavation and embankment limits.--Slope stakes are commonly set to establish limits for open cut such as, channel, ditch, borrow, and structure excavation. They are also used to establish limits for the various types of embankments such as dams, dikes, levees and road fills.

Slope stakes marking the limits and grades for excavations or embankments should be set at each station (100' interval) on tangents, and on horizontal curves having a radius over 750 feet in length. They should be set not to exceed 50' on horizontal curves having a radius less than 750 feet.

Slope stakes should also be set at the following locations:

(1) The P. C. and P. T. of horizontal curves.

(2) Points where there is a break in ground slope or finish grade.

(3) Points where there is a change in planned section, such as:

a. top width of fill,
b. excavated base width,
c. change in slopes,
d. change in berm width, or any other points where a stake is necessary for control of the work.

Slope stakes - excavation.--Slope stakes for excavation are set at the <u>point of intersection of the cut slope with the natural ground</u>. They should be marked to show the vertical distance or cut from the ground at the point where the stake is driven, to the grade elevation for the bottom of the excavation. The stake location is determined by adding the horizontal distance from the centerline to the toe of backslope, plus the berm width, if any, and the quantity obtained by multiplying the cut by the backslope ratio. This total should equal the measured distance from that point to centerline. The location of the slope stake is determined by taking trial readings at right angles to the centerline, until the required conditions are met. A grade reference stake may be driven flush at the same elevation as the ground and should be placed in front of or at the side of the slope stake.

Slope stakes - embankment.--Slope stakes for embankment sections are set at the <u>toe of the slope</u> and should be marked to show the vertical distance from the ground at the point where the stake is driven, to the finished grade elevation for the top of the embankment. The location of the slope stake is determined by taking trial readings at right angles to the centerline. The correct distance from centerline to the point is equal to the slope ratio times the fill from the ground at the point, as related to the plan grade elevation of the embankment, plus the distance from the centerline to the edge of the embankment, (and the width of the berm, when applicable). A reference grade stake may be set flush in front of or to one side of the slope stake.

Slope stakes play an important part in the control of operations for most contract construction. In addition, the staking data is often used in computing final pay quantities. Therefore, all slope stakes should be carefully checked for accuracy in measurement and computation. Distances should be measured horizontal and at right angles to tangent lines or at right angles to the tangent at the point on curves.

All distances and rod readings should be taken to the nearest one tenth (0.1) foot.

Marking and driving slope stakes.--The cut ("C") or fill ("F") should be marked on the front face (side facing the centerline) and near the top of the slope stake. The amount of cut or fill in feet and tenths should be marked immediately below or opposite the "C" or "F". A line should be drawn to separate the feet and tenths marking from the distance from centerline to the slope stake marking. Below or to one side of the distance the slope or fill ratio should be shown. The station number is recorded on the back side and near the top of the slope stake. See Figure 2-1 for suggested methods that may be used to mark construction stakes. Cut or fill sections which include berms cut to

grade may require two stakes to be set at the toe of the fill or top of cut depending on the desire of the contractor. One set as aforementioned for total cut or fill, the other for berm data marked as follows: The cut or fill to design berm elevation, the maximum distance from centerline to point where berm will intersect with outside limit of the cut or fill, and width of berm in feet and tenths. On the same face of the stake print word BERM for identification. Place the station on the back of the stake. Set so cut and fill information faces centerline. If berm is to be graded below toe of fill, reverse the direction of the "berm" stake. See Figures 2-1, 2-2, and 2-3 for typical examples for marking stakes, for excavation or embankments.

All slope stakes should be driven off plumb approximately 30 degrees with the front side of the stake facing up. They should be driven firmly into the ground. (Off set stakes may be driven vertical, if preferred.)

Reference grade stakes.--For dams or other large embankments and for excavations, it is desirable to set reference grade and slope stakes back of and in line with the correctly positioned slope stakes. The reference stakes may be offset five to ten feet or more, and should be marked with the cut or fill in reference to the profile grade and the distance from centerline. They should be marked the same as the slope stakes and the amount of offset should be plainly marked in feet and tenths. Flush elevation hubs may be set in conjunction with the reference stakes. Figures 2-2 and 2-3 illustrate the suggested methods for staking embankments and excavations.

Cross Sections.

Original.--Before taking the original cross sections for a project, the Government representative and the survey party chief should check the drawings and record the stations that require cross sections, and also determine the lateral limit for each section.

Cross sections should be taken at full stations, breaks in the original ground surface and at other intermediate points when necessary to insure an accurate determination of quantities. Original cross sections should always be taken at locations at which the final sections are needed for computing quantities, or to determine compliance with the requirements of the contract. Original cross sections should extend on either side of the centerline well beyond the limits of the work.

When rock or special excavation is anticipated, the original and final cross sections should be taken at more frequent intervals (25-50 feet) to insure more reliable data for quantity determinations.

Extra precaution should be exercised to make sure that the cross sections are taken at right angles to the centerline. In addition to the transit, a right angle prism may be used to establish the direction of the cross section.

Rod and tape readings should be taken at all breaks in the ground surface along the normal line for the full extent of the cross section. The tape should be carefully held in a horizontal plane and may be

read to the nearest foot when the ground surface is quite uniform. For very irregular topography or when taking sections for quantities of materials other than earth, the tape is often read to the nearest tenth (0.10) foot. Rod readings for ground elevations should be recorded to the nearest tenth (0.10) foot. The hand level may be used for completing cross sections in case there are only a few rod readings which cannot be taken with the engineer's level. To maintain good accuracy, the distance from hand level to the rod should not exceed thirty (30) feet.

Borrow areas.--Borrow areas which require measurement of quantities should be cross sectioned or gridded before, and immediately after the excavation is made. The excavated area should be neat and well trimmed to facilitate accurate measurement. If a reference line other than the centerline of the project is used, it should be carefully staked and referenced. Complete field notes should be kept regarding the staking. A sketch should be drawn in the field notes showing the layout of the pit and the base line, and the reference ties to the terminals of the reference line.

Finish stakes.
Prior to setting finish stakes for a structure, a rough check should be made to determine that the work nearly approaches grade. The contractor should be required to do such additional rough grading as necessary before finish stakes are set.

Finish stakes should be set for both line and grade to establish final form for: top of embankments, bottom earth spillways, subgrade for structures and lined sections, and at such other locations as determined necessary by the Government representative. For embankments finish stakes should be set on both shoulder lines and graded to show shoulder finish elevation. Bottom sections of earth spillways should be staked at toe of slope, and such intermediate points as necessary, driven to grade and blue topped.

Finish stakes for subgrade excavation for lined channels and other large structures should be staked and tacked for centerline. The stakes may be driven to finish subgrade elevation if so requested by the contractor.

The spacing of finish stakes should be predetermined with the contractor. For most structures, stakes will not be required to be set on spacing less than 50 foot centers.

The same allowance for settlement should be made when setting finish stakes for dams or other embankments as was provided when setting the original slope stakes. Finish stakes for embankments and for earth excavations should be set to the nearest 0.1 foot, and subgrade for structures and lined sections should be set to the nearest 0.05 foot.

It is common practice to blue the top of finish stakes with crayon ("blue tops"). When the top of a stake is blued it should always indicate that the top of stake is finish grade. Finish stakes that are not driven to grade should never be "blued."

Surveys for Structures.

In staking structures, it is essential that all lines and measurements be absolutely correct. The instrument man should use good standard procedure and refinement in all his work. All layout notes should be checked for possible errors.

Special care should be taken to see that all chaining is within required accuracy. Check measurements should be made. Structure alignment should be established with the instrument set up on the centerline or the reference line for the project. Extreme care must be exercised to determine that all angles are turned accurately and in the right direction. All angles should be turned from a foresight. After an angle has been turned and the stake set on line of sight, the supplemental angle should be measured as a check.

When structures are built on a skew, extra care should be taken to check that the stakes are set with the skew in the proper direction, and that the various angles are accurately measured.

All elevations, as determined, should be compared with the corresponding elevations shown on the drawings, in order that errors on the drawings or in the layout may be detected prior to construction. Natural ground elevations adjacent to the proposed structure should be checked to determine that the structure will fit the site and function properly. If the structure does not fit, adjustments must be made. Elevations, in addition to the foundation or subgrade stakes, may be established later as the job progresses. These additional elevations may be required for various parts of the structure which extend beyond easy access of the initial stake out. The elevations of all structure footings, subgrades and forms should be rechecked before any concrete is poured. The methods for staking various types of structures are illustrated in Figures 2-2, 2-3, 2-4, 2-5, 2-6, 2-7, 2-8, and 2-9. Not all conditions and types of structures are included. The illustrations show the fundamental theory and are sufficiently delineated so that the field engineer will be able to devise good procedures for staking more difficult or special structures in a manner consistent with the general methods indicated.

Standard note keeping procedures are not always established for all types of structure layout. A carefully drawn sketch using identifications such as stationing, letters or other designations to show locations, distances or elevations for the various components will aid materially in documenting the structure layout.

A detail layout drawing may be required to supplement the contract drawings. These drawings should be prepared in the office in advance and checked before making the field layout.

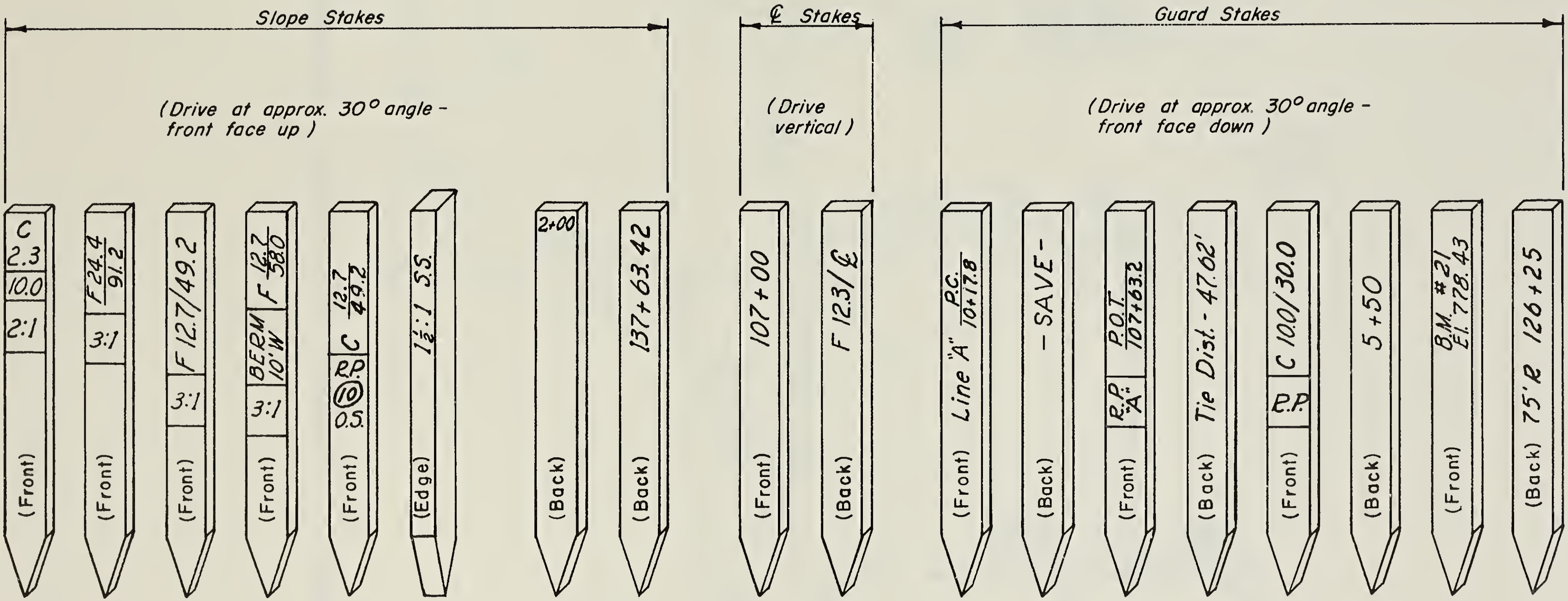


FIGURE 2-1 EXAMPLE FOR MARKING CONSTRUCTION STAKES

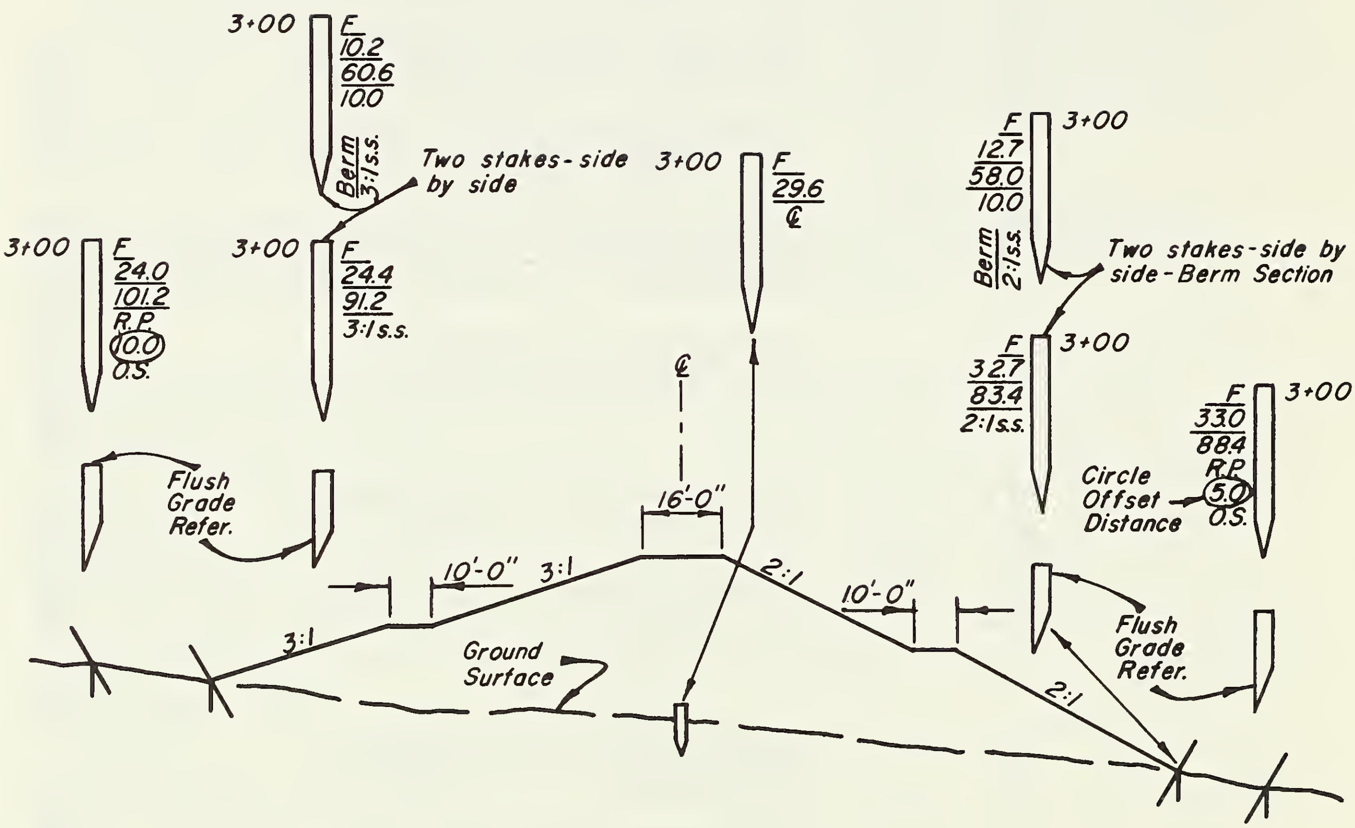


FIGURE 2-2 EXAMPLE FOR STAKING EMBANKMENTS

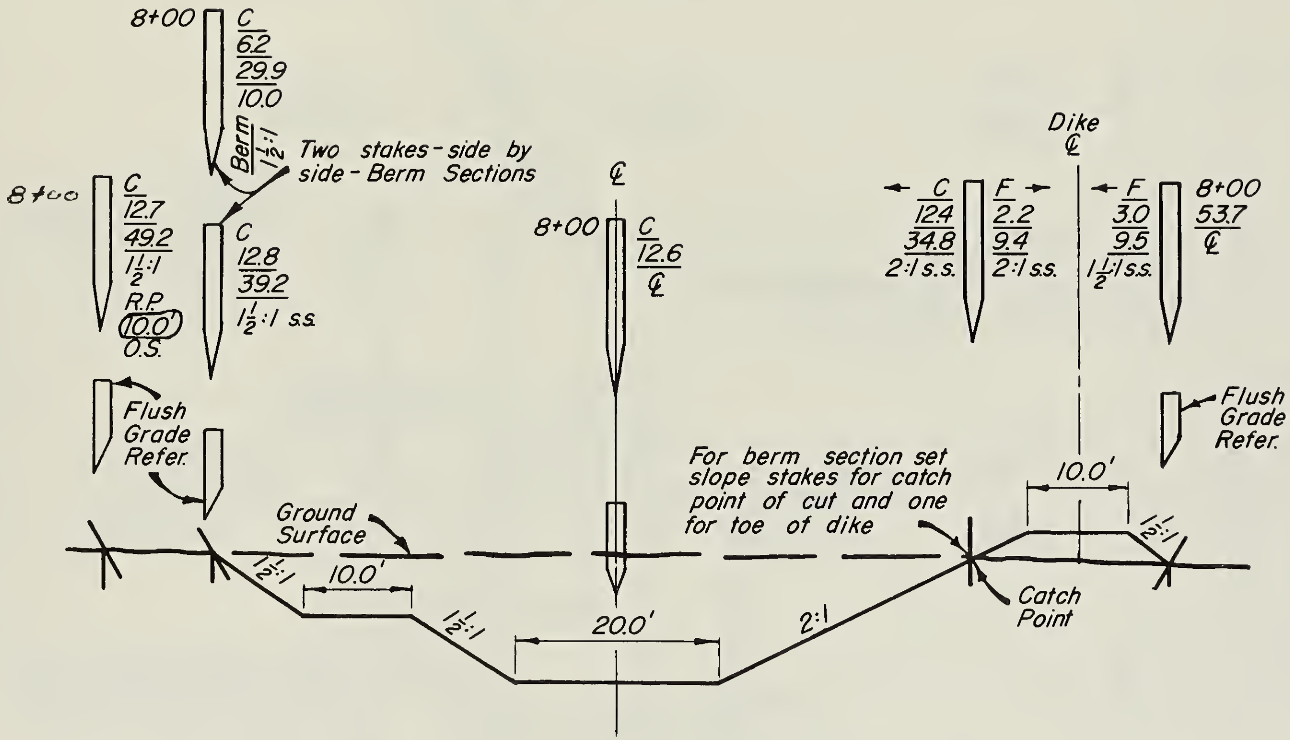


FIGURE 2-3 EXAMPLE FOR STAKING EXCAVATIONS

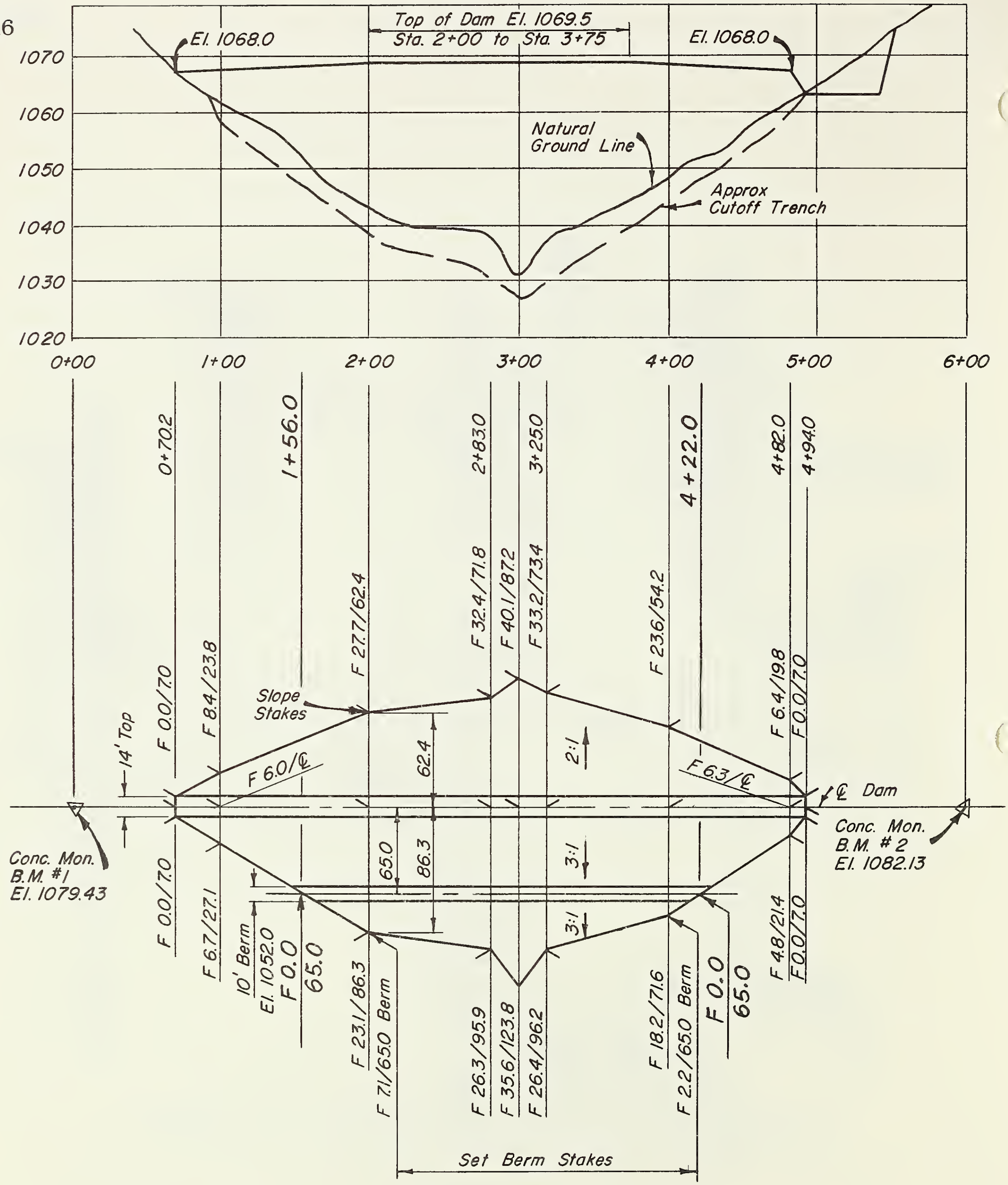


FIGURE 2-4 EXAMPLE FOR STAKING DAM EMBANKMENTS

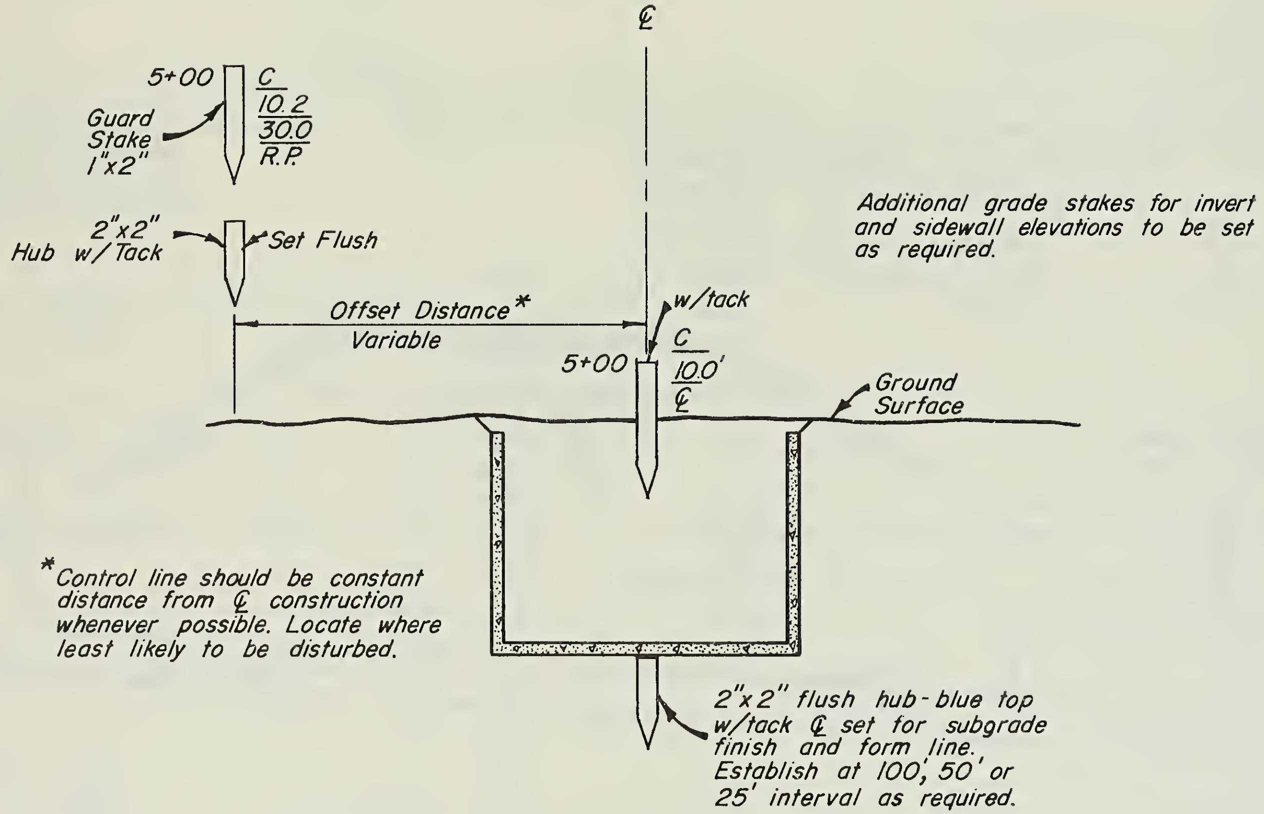


FIGURE 2-5 EXAMPLE FOR STAKING RETANGULAR CHANNEL LINING

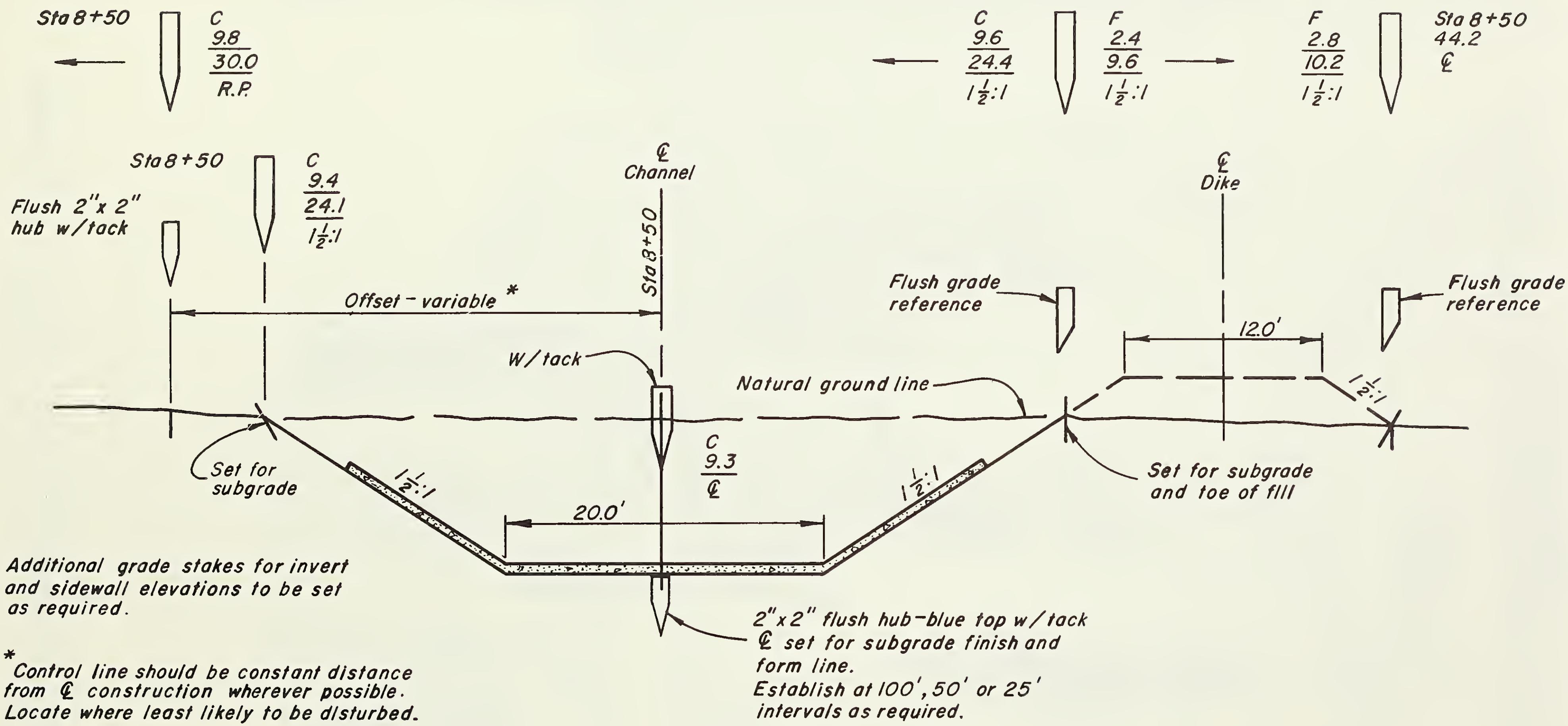
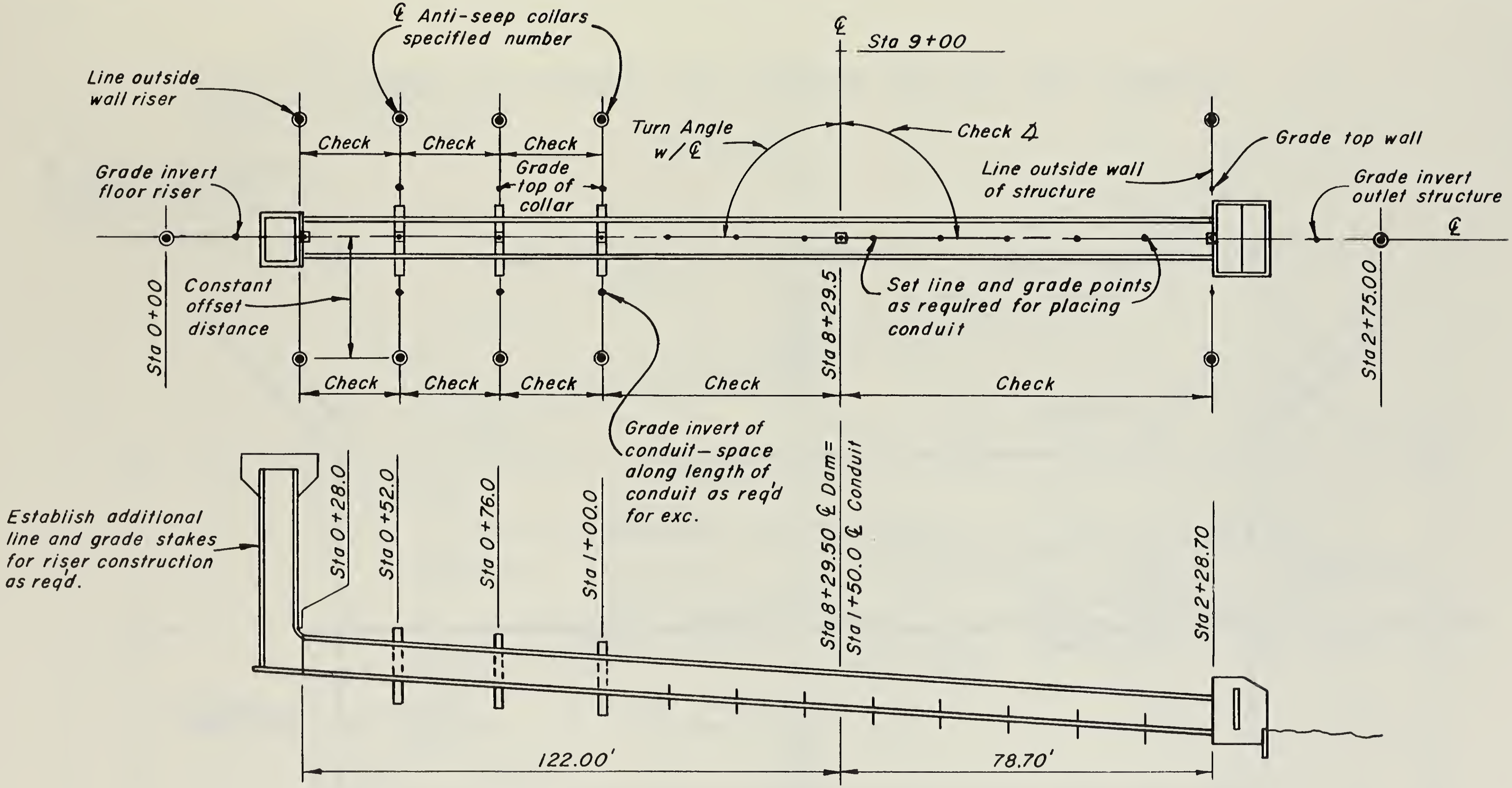


FIGURE 2-6 EXAMPLE FOR STAKING TRAPEZOIDAL CHANNEL LINING



LEGEND

- ◉ Stake or hub with tack on line
- • Elevation stake tacked for line
- ▣ Temporary hub, tacked for stakeout may be reset as blue tops for sub-grade finish.

FIGURE 2-7 EXAMPLE FOR STAKING SINGLE BARREL CULVERTS OR CONDUITS

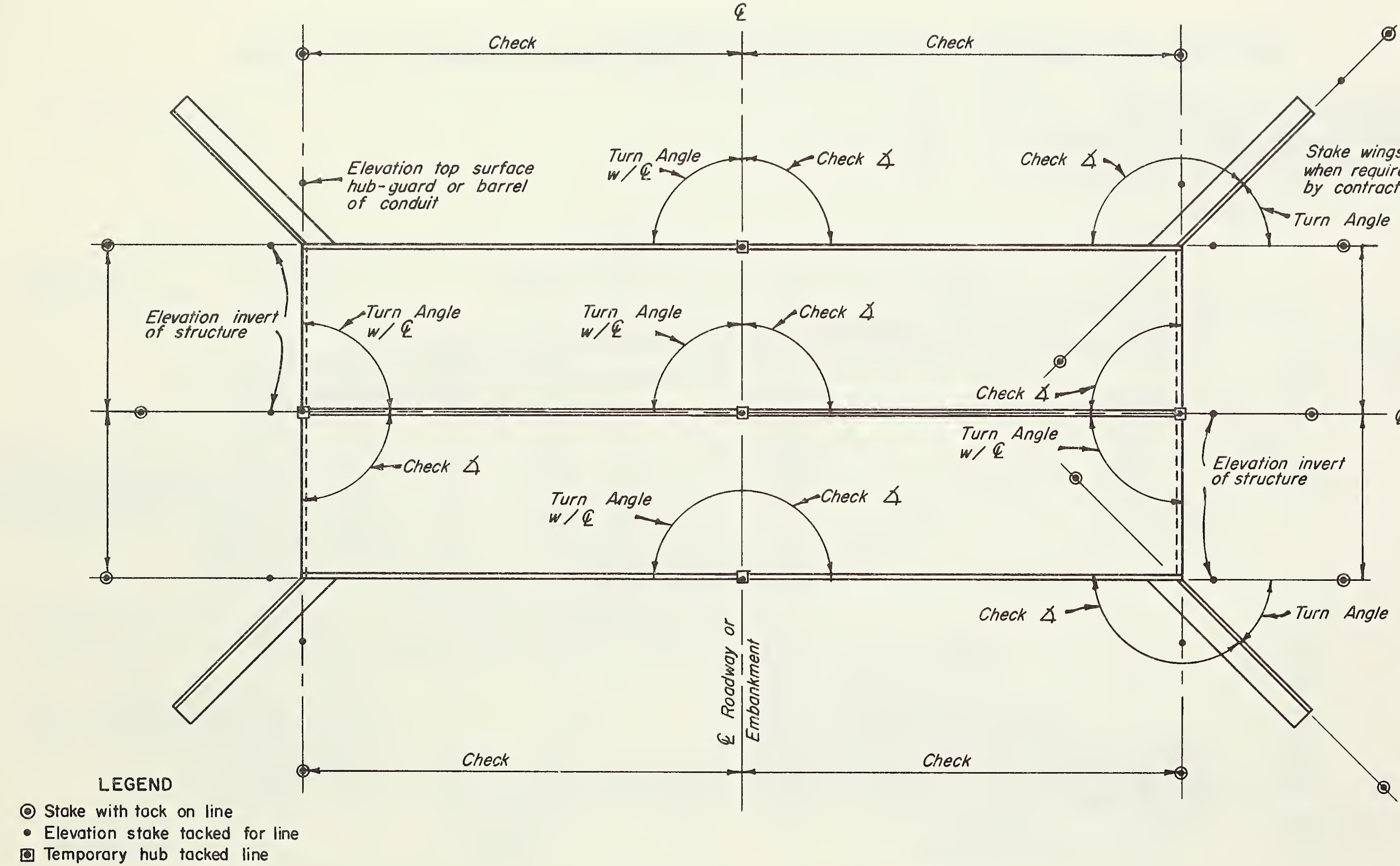


FIGURE 2-8 EXAMPLE FOR STAKING MULTIPLE BOX CONDUITS

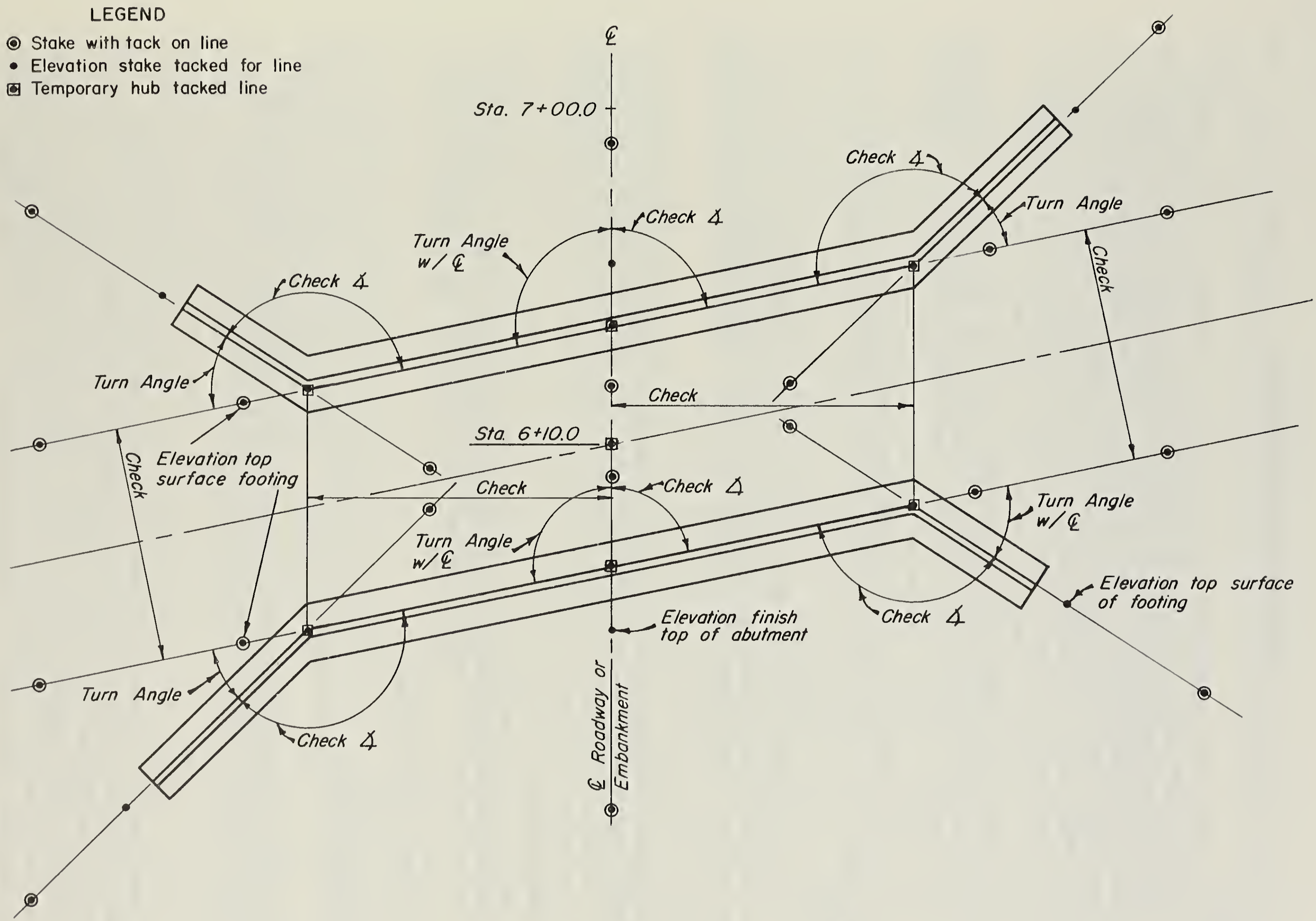


FIGURE 2-9 EXAMPLE FOR STAKING CANTILEVER ABUTMENTS ON SKEW ANGLE

Surveys for Quantities

General.
Quantity surveys are essential for unit price contracts. The contract is awarded on the basis of estimated quantities. Actual quantities may vary from the estimates because of errors; variations in actual site conditions as compared with those on which the estimates were based; necessary additional work required by site conditions; and additions approved under contract modification. The Government representative should be cognizant of the 25 percent clause contained in the general provisions, and should attempt to determine in advance those items which may exceed the limits of this clause so that contract modifications can be prepared prior to doing the work. He must also be familiar with the specific terms of the contract regarding the basis of measurement, the limits, and the method of payments; and he must make sure that his understanding is the same as the contractor's. If there is disagreement the contracting officer and the state office should be notified.

When there are different pay items for a general heading of work (i.e., excavation, stripping, foundation structural, common, rock), it is particularly important that limits for each classification be clearly differentiated in making the quantity surveys.

The Government representative should prepare a list of the pay items that will require before and after surveys for quantity determinations, and so schedule the survey crews that the required sections and measurements are made in proper sequence and with the least inconvenience to the contractor.

Contract items are measured for payment on the unit basis. Work is paid for by units of: length, area, volume, weight, or lump sum. The unit of measurement is given in the specifications and is also indicated in the bid schedule.

Payment Estimates.
As indicated in the general provisions of the contract, monthly progress payments may be made to the contractor. The prompt issuance and transmission of these estimates is a duty of first priority and should be completed without fail on the closing date set for each contract. The Government representative should determine that the items and quantities included for payment are correct and that proper documentation has been made for all items, including allowances for materials delivered at the site, preparatory work, and the amount included for lump sum items. Payment estimates should be based on reliable estimated quantities, supported by the minimum of actual surveys made for the purpose. The inspector's daily reports, day to day construction check shots and other job reports provide information for pay estimates. The acceptability of the estimate data and the field procedures should be as directed by the state staff.

For large structures, especially earth dams, surveys should be made at reasonable intervals to check the accuracy of the reported accomplishments.

Volumes for embankments may be estimated from elevation-volume tables or curves. When construction is performed to the lines and grades shown on the drawings, the original estimate of quantities for each segment of work may be used. Excavation quantities for long ditches or channels may be based on cross sections taken at selected typical locations.

Quantities resulting from over cutting or over filling should not be included for payment if the contract specifies that the payment will be made to the neat lines.

If the contractor requests, and approval is given by the contracting officer, payment may be made for materials delivered on the site, and for preparatory work. Normally, payment for materials will be authorized only in those cases that represent a substantial cost to the contractor, and the item of work involved will not be completed for a prolonged period of time. No estimate for payment should be made until the contractor furnishes invoices for the materials.

Consideration must be given to the invoice price as related to the contract price for the item of work. Deduction in the amount of payment should be made as necessary, to cover the cost of installation of the materials.

Payment estimates may also include partially completed work on lump sum items when so stipulated in the contract. The amount due on these items may be based on the percentage of the item completed, unless other procedures are set forth in the contract.

Quantities for all items of work should be measured by the method, and to the limits specified in the contract including any changes covered by contract modification. Documentation should include the supporting data and the procedures used for estimating each pay item.

All calculations should be carefully prepared and checked. Computations for each pay estimate should be retained in the field office file.

Final Pay Quantities.

All items of work completed under the contract requiring field measurement for final payment should be measured according to United States standard measure. Unless otherwise specified, all lengths and distances are measured horizontally. The field methods to be used for making final quantity surveys should be the method best adapted for each item of work and according to generally accepted standard engineering practice.

It is not anticipated that detail final surveys will be required for all items of work. However, there may be exceptions for certain pay items which will require detail field surveys after completion of the work.

Adequate evidence of satisfactory completion must be available for all phases of the project when preparing final pay quantities.

The need for additional surveys or other data should be determined by the Government representative after careful review of the completed works, the terms of the contract and other available data, such as:

1. Typical cross sections (as constructed)
2. Profiles (as constructed)
3. Field survey notes - elevations and measurements
4. Test reports
5. Material certificates
6. Shop drawings
7. As Built drawings
8. Calculations of quantities for pay estimates.

In computing volumes for excavation and embankment, corrections for curvature will be made when deemed necessary by the Government representative. Final quantities should be based on computed quantities, except as otherwise provided for in the contract. All methods of calculation used should be according to well-recognized engineering principles, and no local rules or customs should be allowed to govern.

All pay items should be computed in the units of measurement and to the degree of accuracy indicated in the contract. Pay items that do not have specified limits for computations should be computed to the degree of accuracy consistent with the unit values of the item. All computations should be carried beyond the decimal point to the extent necessary to avoid cumulative errors. Any changes in method or unit of measurement differing from the contract should be covered by contract modification, and the conversion factor, if any, included in the contract modification.

A systematic method should be established for recording all final quantity calculations. <u>All computations should be checked by a separate party prior to final settlement of the contract</u>. All computations should be preserved for filing with other contract documents.

<u>Engineering Survey Notes for Construction</u>

<u>General</u>.
The following sample plan detail drawings and survey notes for contract construction are included to supplement the standard format data for engineering notes included in Engineering Memorandum SCS-39 (Rev.). Engineering personnel in construction should be familiar with Memorandum 39 and use the standard note keeping procedures outlined therein for Service programs insofar as they apply to contract work.

The use of the grade rod is recommended in the memorandum and the proper procedure for using this method of calculating cuts and fills is discussed under Subsection VIII.

Additional application of this method is shown in the sample notes, Figure 2-23.

Figures 2-10 through 2-15 show components of a flood retarding structure which are typical of the views shown in such standard construction drawings. These exhibits will be referred to in the presentation of the sample field notes for construction. Although the above-mentioned figures and the field notes presented relate primarily to the construction of an earth dam, the content, procedures and completeness for note keeping have direct application for all major construction work.

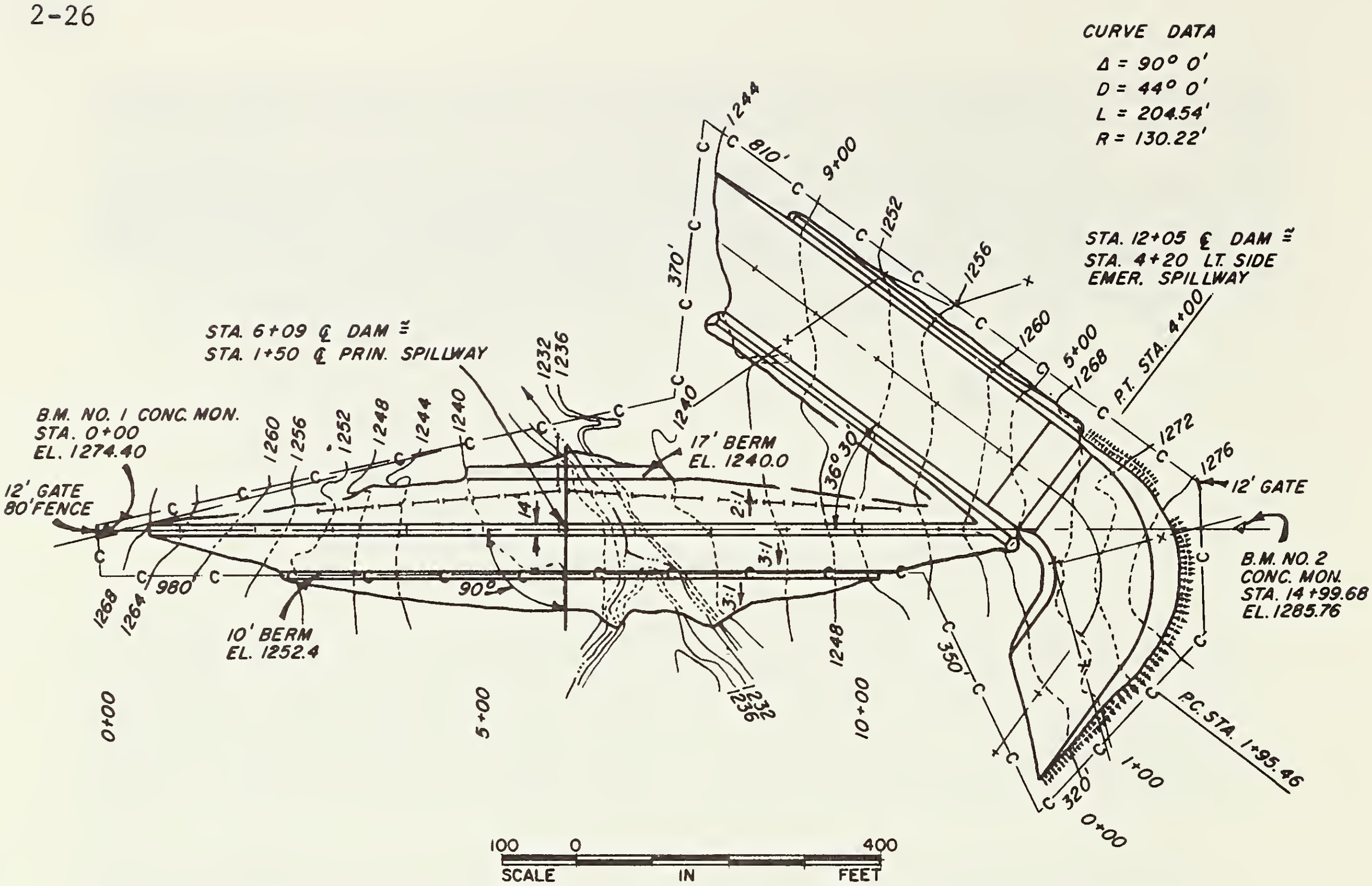


FIGURE 2-10 PLAN OF EMBANKMENT AND SPILLWAYS

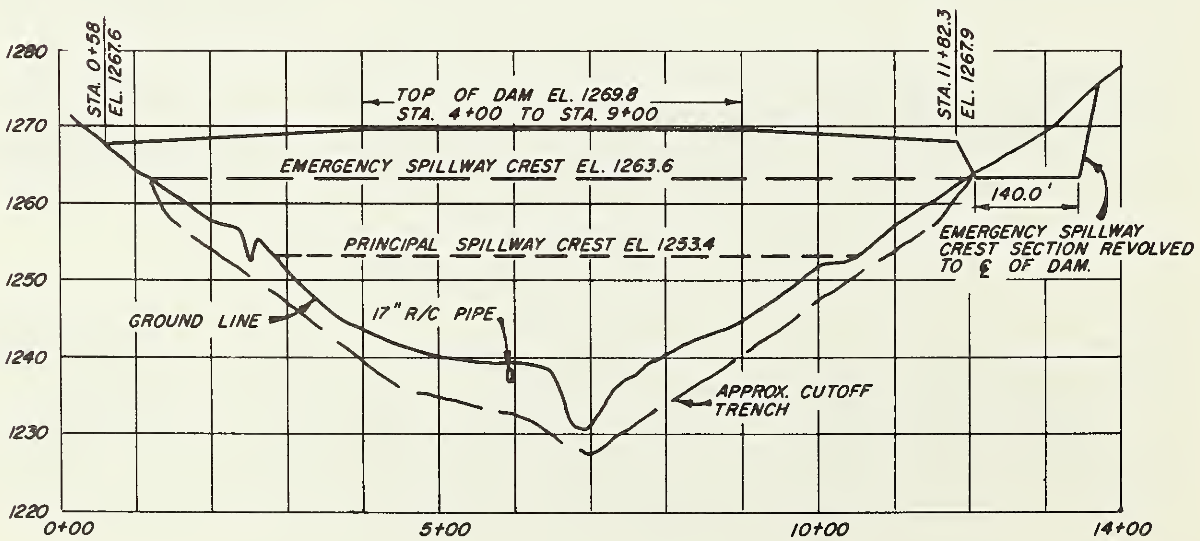


FIGURE 2-11 PROFILE ON ℄ OF DAM

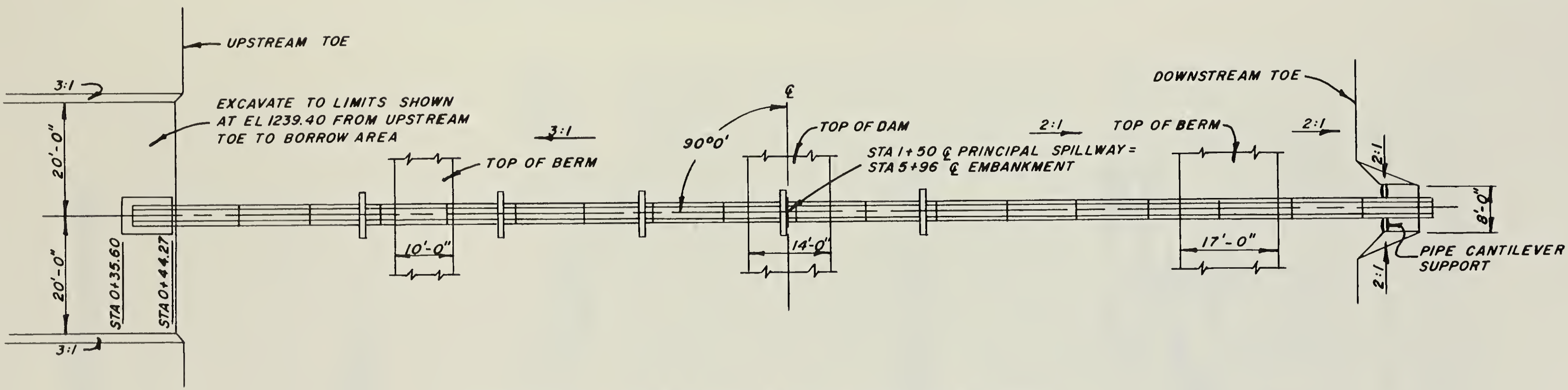


FIGURE 2-12 PLAN OF PRINCIPAL SPILLWAY

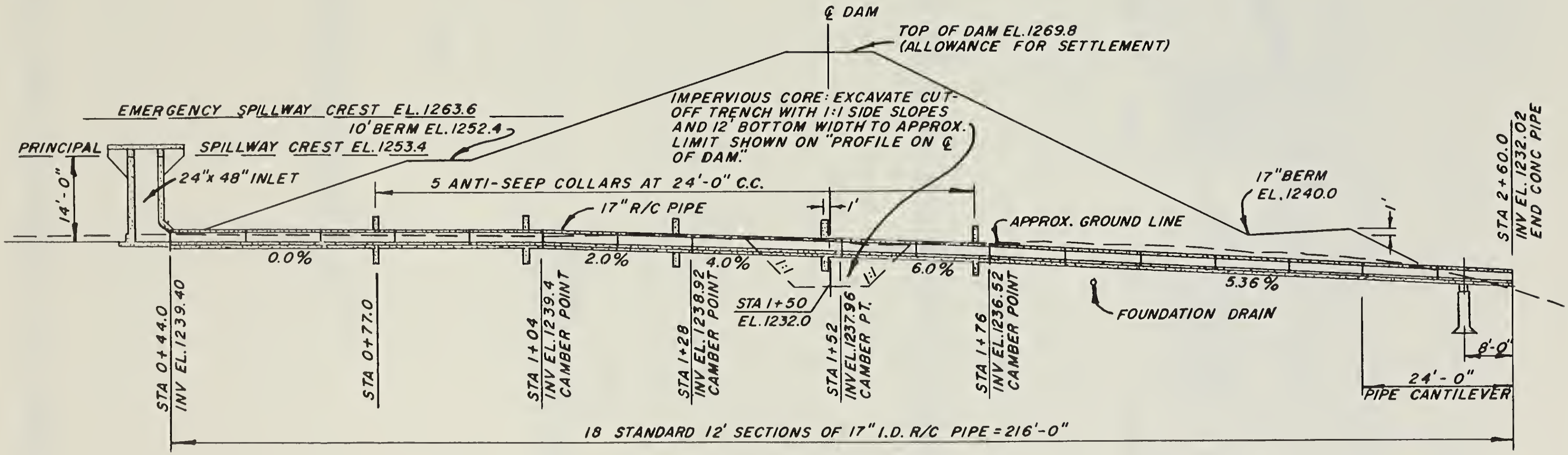


FIGURE 2-13 SECTION ON ℄ OF PRINCIPAL SPILLWAY

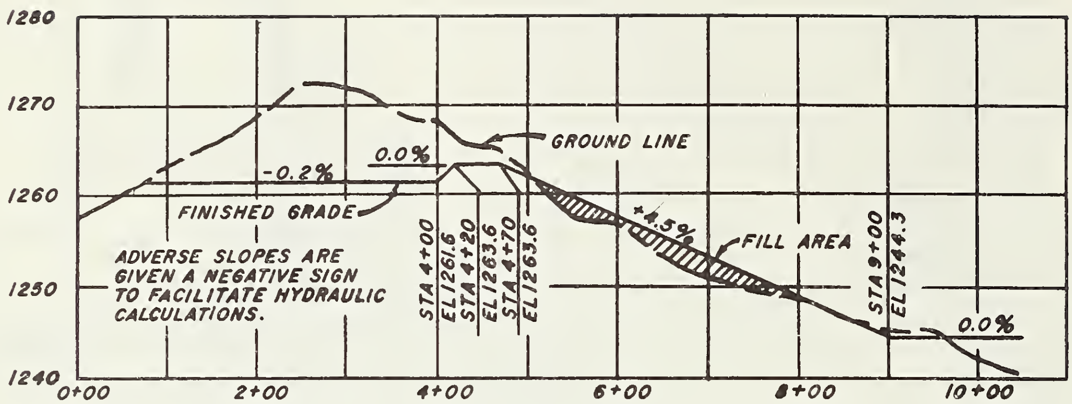


FIGURE 2-14 PROFILE ON ℄ OF EMERGENCY SPILLWAY

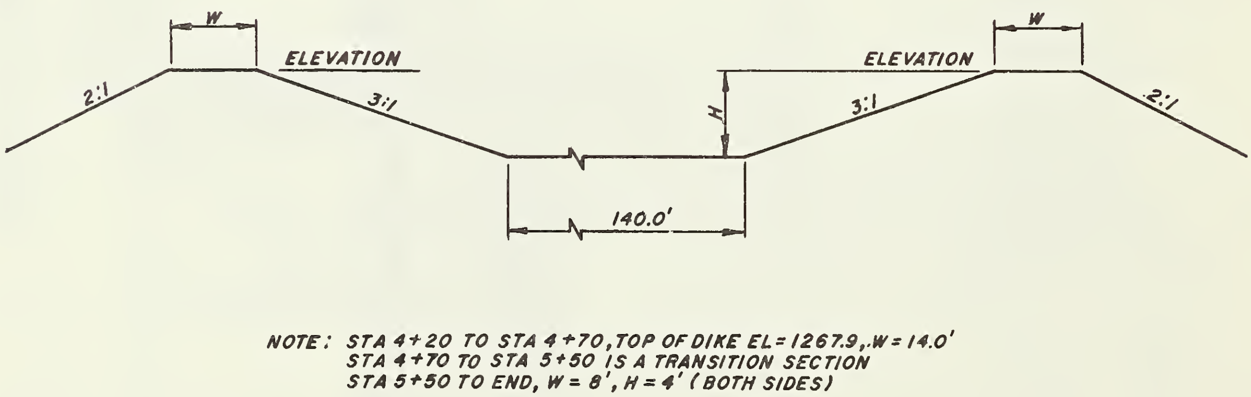


FIGURE 2-15 TYPICAL SECTION - EMERGENCY SPILLWAY

<u>Engineering Notes - Bench Mark Surveys</u>.
The engineering notes shown in Figures 2-16 and 2-17 illustrate a format that may be used when setting and checking bench marks (vertical control) for a construction layout.

It is important to note that B.M. No. 1 and B.M. No. 2 (see Figure 2-10) are permanent monuments, and so recorded on the drawings. Additional bench marks, as required, should be set at convenient locations for use in the construction layout and during the inspection of construction. These BM's should be so located and protected that they will not be disturbed or destroyed for the contract period. Construction benches should be run from the same datum described in the contract construction drawings. <u>All bench mark elevations should be thoroughly checked before other level work is started</u>.

In running bench mark levels or checking bench mark elevations, each bench mark should be used as a turning point. Also, when checking bench mark elevations, the difference between two adjacent bench marks should be compared, rather than the various elevations obtained for a particular bench mark. If the computed difference in elevations for the bench marks shown on the drawings, or those established for construction cannot be verified within the prescribed limits, additional level lines should be run until they do check. For a minor discrepancy, an average to the nearest 0.01 foot may be established as the correct difference in elevation. If one B.M. has a greater elevation than the following bench mark, the difference between them should be considered negative, and vice versa. This procedure should be used to determine the difference between each two adjacent bench marks. Then, beginning with the elevation shown as the construction datum on the drawings, the difference between it and the next bench mark should be added or subtracted, as the case may be, to establish the correct elevation of the second bench mark. In like manner, the correct elevation for each bench mark is determined for the project.

A table forrecording the difference in elevation and the corrected elevation for each bench mark may be prepared as illustrated in Figure 2-18.

Sta.	B.S.	H.I.	F.S. or Grade Rod	Elev. or Planned Elev.	
B.M. #1	0.26	1274.66		1274.40	1274.40
T.P. 1	0.43	1263.85	11.24	1263.42	
T.P. 2	0.15	1252.15	11.85	1252.00	
B.M. #3	0.20	1242.10	10.25	1241.90	1241.90
B.M. #4	10.62	1249.30	3.42	1238.68	1238.68
T.P. 3	11.21	1259.98	0.53	1248.77	
B.M. #5	10.98	1265.30	5.66	1254.32	1254.32
T.P. 4	11.06	1275.95	0.41	1264.89	
T.P. 5	10.89	1286.65	0.19	1275.76	
B.M. #2			0.90	1285.75	1285.76

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SITE 4 Willow Creek John Doe ⊼, ◫
BENCH MARK SURVEY Ray Brown - Rod
Joe Smith - Staker
4-2-63 Fair, Cool, Windy

Concrete Monument - Sta. 0+00 ℄ Dam
Top Stk. - sta. 1+50 ℄ Dam
Top Stk. - sta. 3+00 ℄ Dam
spike in base - S. side of 24" live Oak
200' lt. sta. 4+50 ℄ Dam
spike in base - S. side of 20" Elm
240' lt. sta. 7+00 ℄ Dam
Top Stk. lt. sta. 1+00 ℄ Spillway
spike in base 18" live Oak
175' rt. sta. 7+00 ℄ Spillway
Top Stk. sta. 4+70 ℄ spillway
Top Stk. sta. 13+50 ℄ Dam
Concrete Monument - Sta. 14+99.7 ℄ Dam

FIGURE 2-16 BENCH MARK LEVEL NOTES (ORIGINAL)

SITE 4 WILLOW CREEK Geo. Block ⊼,

Sta.	B.S.	H.I.	F.S. or Grade Rod	Elev. or Planned Elev.		
						B.M. Check levels Ray Brown - Rod
						Joe Smith - Stakes
						4-3-63 Fair, Cool
B.M.#1	0.66	1275.06		1274.40	1274.40	Concrete Momument - sta. 0+00 ℄ Dam
T.P.1	0.52	1264.33	11.25	1263.81		Top stake - sta. 2+00 ℄ Dam
T.P.2	0.88	1254.14	11.07	1253.26		Top stake - sta. 3+50 ℄ Dam
T.P.3	1.68	1245.10	10.72	1243.42		Top stake - sta. 4+00 ℄ Dam
B.M.#3	1.19	1243.05	3.24	1241.86	1241.86	Spike in base of 24" Oak - 200' lt. sta. 4+50 ℄ Dam
B.M.#4	10.91	1249.55	4.41	1238.64	1238.64	Spike in base of 20" Elm - 240' lt. sta. 7+00 ℄ Dam
T.P.4	11.47	1260.39	0.63	1248.92		Top stake - sta. 9+50 ℄ Dam
B.M.#5	11.23	1265.50	6.12	1254.27	1254.27	Spike in base of 18" Oak - 175' rt. sta. 7+00 ℄ spillway
T.P.5	11.61	1276.85	0.26	1265.24		Top stake - sta. 11+50 ℄ Dam
T.P.6	11.72	1287.91	0.66	1276.19		Top of boulder sta. 13+75 ℄ Dam
B.M.#2			2.23	1285.68	1285.68	Concrete Momument - sta. 14+99.7 ℄ Dam
RECHECK						
B.M.#1	0.31	1274.71		1274.40	1274.40	Concrete Monument sta. 0+00 ℄ Dam
T.P.1	0.80	1264.07	11.44	1263.27		
T.P.2	0.77	1253.71	11.13	1252.94		
B.M.#3			11.85	1241.86	1241.86	Spike in base 24" Oak

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FIGURE 2-17 BENCH MARK LEVEL NOTES (CHECK)

Sta.	B.S.	H.I.	F.S. or Grade Rod	Elev. or Planned Elev.	

ADJUSTMENT OF B.M. LEVELS

SITE 4: WILLOW CREEK CONSTRUCTION B.M.'s

Computed by: John Doe 4-5-63

Checked by: Geo Black 4-6-63

B.M. No.	Sta.	ORIGINAL Elev.	ORIGINAL Diff.	1ST CHECK Elev.	1ST CHECK Diff.	2ND CHECK Elev.	2ND CHECK Diff.	ADJUSTED DIFFERENCE	CORRECTED ELEVATION
1	0+00	1274.40		1274.40		1274.40			1274.40
			-32.50		-32.54		-32.54	-32.54	
3	4+50	1241.90		1241.86		1241.86			1241.86
			-3.22		-3.22			-3.22	
4	Lt. 7+00	1238.68		1238.64					1238.64
			+15.64		+15.63			+15.64	
5	Rt. 7+00	1254.32		1254.27					1254.28
			+31.43		+31.41			+31.42	
2	14+99.7	1285.75		1285.68					1285.70

TOTAL PLUS = 47.06

TOTAL MINUS = 35.76

NET DIFFERENCE = +11.30

1274.40 + 11.30 = 1285.70

CHECK

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FIGURE 2-18 BENCH MARK ELEVATION (AJUSTED)

Engineering Notes -- Construction Grades -- Embankment, Cut-off Trench and Principal Spillway.

Figure 2-19 shows the planned construction grades for the embankment, cut-off trench, and the principal spillway for the proposed dam as shown in example views of the construction drawings, Figures 2-10 through 2-13.

Prior to layout, it is desirable to tabulate pertinent elevations for all the major structure elements. This information should be placed in the proper construction field note books. The survey party chief has definite need for this information to expedite layout and checking. For large complex structures the inspector may also find it convenient to have certain elevations, dimensions and other detail job data tabulated for quick reference.

Elevations for earthwork are usually computed to the nearest one-tenth (0.1) foot. Where grades or control elevations are not shown on the drawings, control elevations required for computing grades for staking rough grading may be established by scaled measurements taken from the drawings.

It is common practice to compute grades for the various elements of structures to the nearest one-hundredth (0.01) of a foot.

All construction grades should be computed to show finish elevation. Extra columns may be added to the notes to record subgrade or other specific construction datums for layout, if the contractor requests that the stakes reflect this information.

Sta.	B.S.	H.I.	F.S. or Grade Rod	Elev. or Planned Elev.	
SITE 4 - WILLOW CREEK					
Planned Elevations					
Computed by: John Doe 3-26-63					
Checked by: Ray Brown 3-28-63					
Top of Embankment And					
Bottom of Cutoff Trench					
Sta.	Emb.	Cut-off	Sta	Emb.	Cutoff
0+58.0	1267.6		6+50	1269.8	1224.8
1+00	1267.9		7+00	1269.8	1227.0
1+25	1268.0	N.G. 1263.1	7+50	1269.8	1230.5
1+50	1268.2	1258.0	8+00	1269.8	1234.0
2+00	1268.5	1254.3	8+50	1269.8	1237.5
2+50	1268.8	1250.7	9+00	1269.8	1241.0
3+00	1269.1	1247.0	9+50	1269.4	1244.0
3+50	1269.4	1243.7	10+00	1269.1	1247.5
4+00	1269.8	1239.7	10+50	1268.8	1251.0
4+50	1269.8	1236.0	11+00	1268.5	1254.0
5+00	1269.8	1234.8	11+50	1268.2	1257.0
5+50	1269.8	1233.7	11+82.3	1267.9	
6+00	1269.8	1232.5	12+00	—	N.G.
	N.G. - Natural ground				

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Sta.	B.S.	H.I.	F.S. or Grade Rod	Elev. or Planned Elev.	
SITE 4 WILLOW CREEK					
Planned Elevations					
Computed by: John Doe 3-26-63					
Checked by: Ray Brown 3-28-63					
PRINCIPAL SPILLWAY					
Sta.	F.L. GRADE	SUB GRADE	REMARKS		
0+35.6	1239.40	1238.57	Riser base		
0+39.9	1253.40		℄ and crest - Riser		
0+44	1239.40	1238.57	U.S. Inv. Conc. Pipe Cond.		
0+44.27	1239.40	1238.57	Riser base		
0+44.31	1239.40	1238.67	U.S. end Conc. cradle		
0+77	(1243.55) ← top of collar 1239.4	1236.17	Anti-seep Collar #1		
1+01	(1243.55) 1239.40	1236.17	Anti-seep Collar #2		
1+04	1239.40	1238.67	Camber point (-2.0%)		
1+25	(1243.13) 1239.00	1235.75	Anti-seep Collar #3		
1+28	1238.92	1238.19	Camber point (-4.0%)		
1+49	(1242.23) 1238.08	1234.85	Anti-seep Collar #4		
1+52	1237.96	1237.23	Camber point (-6.0%)		
1+73	(1240.85) 1237.70	1233.47	Anti-seep Collar #5		
1+76	1236.52	1235.79	Camber point (-5.36%)		
2+52	1231.72	1223.72	Conduit support		
2+60	1232.02	1231.29	D.S. Inv. Conc. Pipe Cond.		

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FIGURE 2-19 EXAMPLE CONSTRUCTION GRADES

Engineering Notes -- Construction Grades -- Emergency Spillway. Figure 2-20 shows a format for recording planned elevations and other construction detail for the emergency spillway shown in Figures 2-10, 2-14, and 2-15.

Elevations for earthwork are computed to the nearest one-tenth (0.1) foot. All elevations are computed to finish grade. Construction stakes may be set to show elevation for over excavation, if such excavation is specified, and the contractor so requests. For this situation, the notebook should include a column showing the additional elevations to be used for staking.

Sta.	B.S.	H.I.	F.S. or Grade Rod	Elev. or Planned Elev.	
SITE 4 - WILLOW CREEK					
Planned Elevations					
Computed by: John Doe 3-26-63					
Checked by: Ray Brown 3-26-63					
EMERGENCY SPILLWAY - BOTTOM OF CHANNEL					
Sta.	Elev.	Grade	Sta.	Elev.	Grade
0+00	1260.8		5+00	1262.3	
0+50	1260.9		5+50	1260.1	
1+00	1261.0		6+00	1257.8	
1+50	1261.1		6+50	1255.6	
1+95.46	1261.2	-0.2%	7+00	1253.3	+4.5%
2+50	1261.3		7+50	1251.1	
3+00	1261.4		8+00	1248.8	
3+50	1261.5		8+50	1246.6	
4+00	1261.6		9+00	1244.3	
4+20	1263.6		9+50	1244.3	0.0%
4+70	1263.6	0.0%	10+00	1244.3	
Bottom width = 140.0'					

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Sta.	B.S.	H.I.	F.S. or Grade Rod	Elev. or Planned Elev.	
SITE 4 WILLOW CREEK					
Planned Elevations					
Computed by: John Doe 3-27-63					
Checked by: Ray Brown 3-29-63					
EMERGENCY SPILLWAY - TOP OF DIKE					
Sta.	Top Elev.	Crown Width			
4+00	N.G.				
4+20	1267.9	14'			
4+70	1267.9	14'			
5+50	1264.1	UNIFORM TRANSITION			
6+00	1261.8				
6+50	1259.6				
7+00	1257.3				
7+50	1255.1				
8+00	1252.8	8' Top			
8+50	1250.6				
9+00	1248.3				
9+50	1248.3				
Channel bottom width = 140.0'					

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FIGURE 2-20 EXAMPLE CONSTRUCTION GRADES

Engineering Notes -- Construction Layout -- Embankment and Cut-off Trench.

Figure 2-21 illustrates a format that may be used to record the layout notes for dams or other embankments. The elevations and structure dimensions illustrated were taken from plan data shown in Figures 2-10 and 2-11. Computed construction grades, illustrated by Figure 2-19 may be used to set up the field note book, and they also should be available for reference during the survey layout.

The notes taken in the field at the time of the layout may also be used to plot the ground surface and the cross sections as required for quantity computations.

Separate surveys may be made for staking the limits of the embankment and the cut-off trench if the complexity of the work or other causes justify separate surveys.

Sta.	B.S.	H.I.	F.S. or Grade Rod	Elev. or Planned Elev.	
				Embank. Elev. & Grade Rod	Cutoff Elev. & Grade Rod
Sta.	+	H.I.	−		
B.M#1	0.32	1274.72		1274.40	
0+58				1267.6 7.1	
T.P.	0.43	1264.94	10.21	1264.51	
1+00				1267.9 -3.0	
1+25					1263.1 1.8
1+50				1268.2 -3.3	1258.0 6.9
2+00				1268.5 -3.6	1254.3 10.6
Start 10' berm U.S. - El. 1252.4 - Sta. 2+45					
2+50				1268.8 -3.9	1250.7 14.2
T.P.	0.71	1252.78	12.87	1252.07	
3+00				1269.1 -16.3	1247.0 5.8

SCS-29 (3-60)

GPO : 1960 OF—550816

SITE 4 - WILLOW CREEK — John Doe ⊼, ☐☐

Cross Sections & Embankment - Cutoff Layout — Ray Brown Rod, Joe Smith Stakes

4-3-63 Fair, cool, windy — Sam Jones tape

DOWNSTREAM (2:1) — (CUTOFF 1:1) — UPSTREAM (3:1)

Concrete Monument 0+00 ℄ Dam — F 0.0 / 7.1 / ℄

Top of stake sta. 1+00 ℄ Dam

OFFSET (10')							OFFSET (10')
F4.1 / 1.1 / 25.0	F4.0 / 1.0 / 15.0		F3.7 / 0.7 / ℄			F3.4 / 0.4 / 17.2	F3.3 / 0.3 / 27.2
			C0.0 / 1.8 / ℄				
(10') F5.0 / 1.7 / 29.0	F6.0 / 2.7 / 19.0	C3.2 / 3.7 / 9.2	F7.0 C3.2 / 3.7 / ℄	C3.3 / 3.6 / 9.3	F9.8 / 6.5 / 36.4		(10') F10.8 / 7.5 / 46.4
(10') F7.0 / 3.4 / 35.0	F9.0 / 5.4 / 25.0	C3.7 / 6.9 / 9.7	F10.7 C3.5 / 7.1 / ℄	C3.4 / 7.2 / 9.4	F12.3 / 8.7 / 43.9		(10') F12.6 / 9.0 / 53.9
(10') F13.7 / 9.8 / 44.4	F13.7 / 9.8 / 34.4	C4.4 / 9.8 / 10.4	F14.1 C4.0 / 10.2 / ℄	C4.1 / 10.1 / 10.1	F0.2 / Berm / 66.2	F16.6 / 12.7 / 66.8	(10') F16.8 / 12.9 / 76.8

Top of stake sta. 3+00 ℄ Dam

(10') F16.5 / 0.2 / 50.8	F16.9 / 0.6 / 40.8	C4.2 / 1.6 / 10.2	F18.0 C4.1 / 1.7 / ℄	C3.9 / 1.9 / 9.9	F3.1 / Berm / 67.1	F19.8 / 3.5 / 76.4	(10') F20.3 / 4.0 / 86.4

FIGURE 2-21 EMBANKMENT AND CUTOFF TRENCH LAYOUT

Engineering Notes -- Construction Layout -- Simple Curve. Figure 2-22 illustrates the format and the notes that should be recorded preparatory to the layout of a simple curve.

The information exhibited refers to the layout of the centerline of the emergency spillway for the dam shown in Figure 2-10.

Simple curves are frequently required in the layout of works of improvement, which may involve construction of embankments, excavations or elements of structures.

Stationing for the project should be continued along the centerline of the curve at the time of stakeout, and these stations should be used as control points for cross sections and the staking of the structure limits. Transverse measurements are made normal to the tangent to the curve at the point under consideration. This measurement line parallels an imaginary line that passes through the centerline station and the reference or radius point for the curve.

Sta.	B.S.	H.I.	F.S. or Grade Rod	Elev. or Planned Elev.	
Sta.		Defl. ∡			
P.T. 4+00		45°00'			
3+75		39°30'	CURVE DATA		
			Δ = 90°00'		
3+50		34°00'	D = 44°00'		
			L = 204.54'		
3+25		28°30'	R = 130.22'		
			T = 130.22'		
3+00		23°00'			
			P.C. Sta. 1+95.46		
2+75		17°30'	P.T. Sta. 4+00		
2+50		12°00'			
2+25		6°30'			
2+00		1°00'			
P.C. 1+95.46		0°00'			

SCS-29 (3-60) GPO . 1960 OF—550816

SITE 4 WILLOW CREEK
Emergency Spillway
Curve Layout

John Doe ⊼, ☐
Ray Brown - Rod
Sam Jones - Tape
4-1-63, Clear, cool

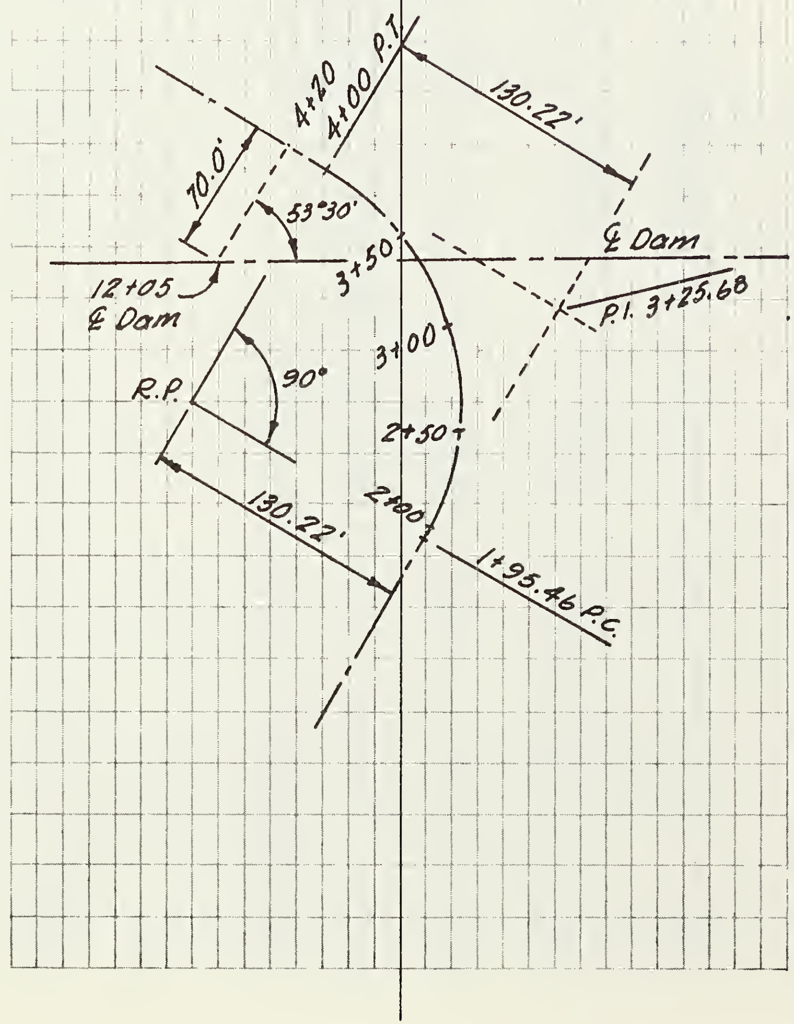

FIGURE 2-22 SIMPLE CURVE LAYOUT

Engineering Notes -- Construction Layout - Emergency Spillway. Figure 2-23 illustrates a format that may be used for recording notes for the cross sections and the layout of the emergency spillway or other earth work. The work may consist of excavation, or sections which combine excavation and embankment.

The layout and the elevations for this example were taken from the computed plan grades shown in Figure 2-20.

The necessary information for the layout, and the preparation of the plan grades, is shown in Figures 2-14 and 2-15.

Sta.	B.S.	H.I.	F.S. or Grade Rod	Elev. or Planned Elev. Elev. Top Dike & Grade Rod	Elev. ℄ Spillway & Grade Rod	SITE 4 WILLOW CREEK Cross Sections and Emergency Spwy. Layout	John Doe ⊼, ☐ Ray Brown - Rod Sam Jones - Tape Joe Smith - Stakes 4-4-63 Clear, Warm
B.M.#2	0.21	1285.91		(corr'd.el.) 1285.70		Conc. Monument - Sta.	14+99.7 ℄ Dam
T.P.	0.34	1274.99	11.26	1274.65		Top of stake	
T.P.	3.41	1269.98	8.42	1266.57		Top of stake	OFFSET
						OFFSET	5'
0+15					1260.8 / 9.2		C0.0 / 9.2 / 70.0 ; C0.2 / 9.0 / 75.0
							5'
0+50					1260.9 / 9.1		C0.0 / 9.1 / 50.0 ; C0.8 / 8.3 / 72.4 ; C1.0 / 8.1 / 77.4
						5	5'
1+00					1261.0 / 9.0	F0.2 / 9.2 / 75.0 ; C0.0 / 9.0 / 60.3 ; C0.6 / 8.4 / 20.0	C1.1 / 7.9 / ℄ ; C2.6 / 6.4 / 40.0 ; C4.1 / 4.9 / 82.3 ; C4.3 / 4.7 / 87.3
						5'	5'
1+50					1261.1 / 8.9	C1.8 / 7.1 / 81.3 ; C2.1 / 6.8 / 76.3 ; C3.4 / 5.5 / 40.2	C4.9 / 4.0 / ℄ ; C7.4 / 1.5 / 45.0 ; C8.3 / 0.6 / 94.9 ; C8.5 / 0.4 / 99.9
T.P.	1.14	1262.90	8.22	1261.76		Top of stake	
6+00				1261.8 / 1.1	1257.8 / 5.1	2:1 F8.2 / 9.3 / 116.6 ; 3:1 F7.4 / 8.5 / 70.0 ; F3.4 / 8.5 / 70.0 ; F2.6 / 7.7 / 35.0	F1.6 / 6.7 / ℄ ; C0.0 / 5.1 / 50.2 ; C0.8 / 4.3 / 70.0 ; 3:1 F3.2 / 4.3 / 70.0 ; 2:1 F3.0 / 4.1 / 93.6
						5' F8.3 / 9.4 / 121.6	5' F3.1 / 4.2 / 98.6

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FIGURE 2-23 EMERGENCY SPILLWAY LAYOUT

Engineering Notes -- Construction Layout - Principal Spillway. Figure 2-24 illustrates a format that may be used for recording the layout notes for the construction of principal spillways for flood control dams, and can also be readily adapted for use in laying out other types of closed conduits or culverts.

Information required for preparing the layout sketch including the control elevations was recorded from the contract drawings.

The example notes were developed from the dimensions and elevations illustrated in Figures 2-12 and 2-13.

Planned elevations as prepared for this phase of the project, Figure 2-20, should also be available to the survey party at the time of layout.

Sta.	B.S.	H.I.	F.S. or Grade Rod	Elev. or Planned Elev.	
Sta. as shown on Plan = 6+09.0					
Sta. as staked = 6+02.0					
Change location to fit downstream channel					
Type Str. - 17" diam. R/C Pipe w/ 6" R/C Cradle					
Point	B.S.	H.I.	F.S.	Elev.	Plan Elev.
B.M #3	1.06	1242.92			1241.86
Grd. @ ℄ Str.			2.1	1240.8	1240.5
Grd. @ ℄ Riser			0.3	1242.6	1241.8
Grd. @ outlet			10.6	1232.3	1231.9
Str. Chan 150' rt.			12.3	1230.6	1230.3
Str. Chan 200' rt.			14.7	1228.2	1227.9
"A" F.L. Slab & Cond.			0.25	1242.67	C 3.27 1239.40
"C" #1 Cutoff F.L.			1.10	1241.82	C 2.42 1239.40
"C₁" #1 Cutoff Topwall			1.65	1241.27	F 2.28 1243.55
"D" #2 Cutoff F.L.			1.96	1240.96	C 1.56 1239.40
"D₁" #2 Cutoff Topwall			2.61	1240.31	F 3.24 1243.55
↓					
"H" Subgrade Cond. Sup't.			9.96	1232.96	C 9.24 1223.72
"H₁" Top Cond. Sup't.			10.71	1232.21	C 0.49 1231.72
"B" F.L. End Cond.			10.90	1232.02	C 0.0 1232.02
T.P.	6.87	1241.16	8.63	1234.29	
BM #4			2.51	1238.65	1238.64

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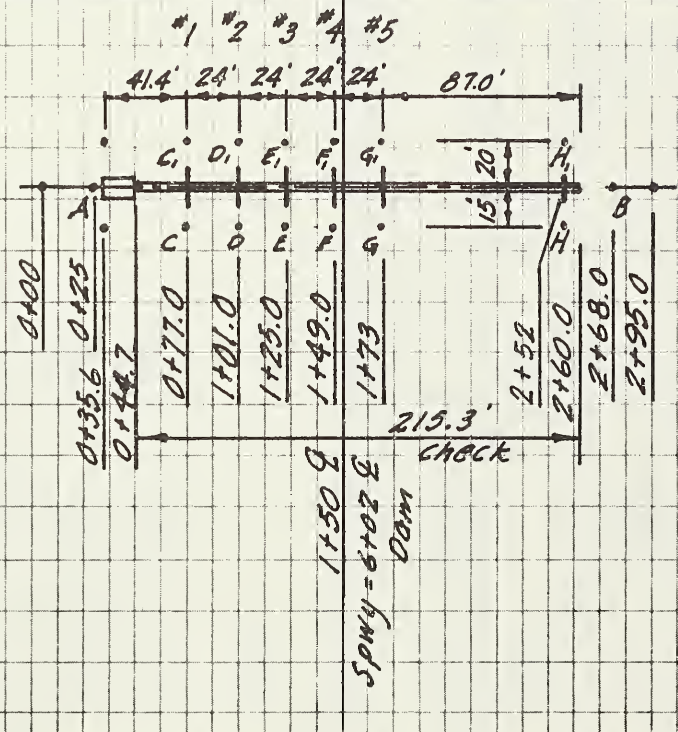
SITE 4 WILLOW CREEK — John Doe ⊼ , ⌸
Principal Spillway — Ray Brown Rod
Layout — Joe Smith Stakes
Sam Jones Tape
4-5-63 Clear, windy

Spike in base 24" Oak - 200' Lt. Sta. 4+50 ℄ Dam



Spike in base 20" Elm 240' Lt Sta. 7+00 ℄ Dam

FIGURE 2-24 PRINCIPAL SPILLWAY

NATIONAL ENGINEERING HANDBOOK

SECTION 19

CONSTRUCTION

CHAPTER 3. INSTALLATION

General

The detail requirements for the quality of materials and the installation of the specified items of work are contained in the drawings and specifications or other contract documents for the project. All personnel involved in contract administration should become intimately familiar with the construction requirements. There is no substitute for complete knowledge of the contract drawings and specifications.

In case of conflict between contract requirements (drawings and specifications) and suggestions contained in this handbook, the former shall govern. Also, it is not intended that all items included in any given check-list contained in this chapter will apply to all contracts. The inspector should carefully review the suggestions presented and determine the "check" items that apply for each phase of the contract.

It is equally important to review the check-lists in relation to the requirements outlined in the contract to make sure that the contract covers all the important requirements for construction.

It is necessary that those responsible for inspection should have a comprehensive knowledge of the grades and standards of workmanship recognized by the engineering profession and by responsible contractors as attainable and appropriate for the various kinds of construction operations.

The Government representative must take action as required to see that the construction requirements of the contract are enforced. At no time should any detail called for in the drawings or specifications be interpreted to allow for reduction in quality, strength, or appearance unless the contract is properly modified and approved.

It is essential that all materials be inspected prior to use in the work. Materials that do not meet the contract requirements as determined by visual inspection, certification or test, should be rejected unless the contracting officer determines that it is advisable to accept the materials by contract modification. The inspector should dedinitely list in the Job Diary all materials that do not meet the requirements and the reasons for rejection. Also, he may, when required by the state staff, make proper entries in the Job Diary for each item of material inspected even though found to meet all the requirements of the contract.

Clearing and Grubbing

General.
Clearing and grubbing are usually the first items of work performed under a contract. Proper performance of these operations is necessary to insure the stability of slopes and embankments within the limits of the construction site. Improper operations may increase the cost for operation and maintenance of the project.

Prior to doing the clearing and grubbing operation, the Government representative or the inspector should walk the job with the contractor so that he may become familiar with the clearing and grubbing limits. Other items to consider at this time include utilities which could be damaged; methods of operations and disposal; and any stakes, trees, building, fences, or facilities to be saved or protected.

Inspector's Check List.
The following important activities, if included in the contract, should be given special attention by the inspector to assure their completion at the proper stage of clearing and grubbing activities:

1. That limits for clearing and grubbing are adequately marked by use of stakes, paints, flags, etc.

2. That limits of fence removal are properly marked.

3. Advise contractor of the locations for storing salvaged material, such as fencing, timber or other.

4. That trees to be protected and trees to be salvaged are properly marked.

5. That salvaged logs are cut to specified lengths and safely piled or decked.

6. That trees are cut to specified limits above ground.

7. That stumps, roots, and other vegetation are removed to specified depths and that holes are backfilled as required.

8. That adequate safeguards are used to prevent damage to existing structures and utilities by clearing operations.

9. That applicable laws and safety codes are observed in the storage and use of explosives.

10. Inspect the following items and advise the contractor of any needed action for safety of operations.

    (a) Condition of hand and power tools.

    (b) Spacing of workmen on hand clearing.

(c) Proper warning to workmen and public during blasting or work of extreme hazard.

(d) Posting of signs to prevent use of radio equipment in the vicinity of blasting operations.

(e) Adequate logging cabs on tractors for protection of operators.

(f) Felling and bucking operations on steep slopes, slippery terrain and rock outcrops.

(g) Adequacy of haul roads for logging trucks.

11. Know burning regulations, local fire district, county, state and federal agencies and see that contractor abides by the regulations.

12. Require attendant and standby fire fighting equipment if regulations or specifications so indicate..

13. Require complete disposal of all specified woody material and other debris in accordance with the contract.

14. Require completion, including disposal, in accordance with the operations time schedule when specified in the contract.

15. Do not permit burning on the surface of revetments, surfaced roads or other structures, or under overhead utility lines.

16. Record all quantities and Job Diary entries.

Removal of Obstructions

Public Utilities.
The preparation of the site often requires the removal or relocation of public utilities such as telephone, power, water and gas lines. Normally this work will be performed by the organization owning and/or operating the facility. Unless otherwise specified, the contractor is responsible for the protection and safeguarding of all utilities located within the limits of the work area during the performance period of the contract.

Structures or Other Obstructions.
The work included in this category may consist of the removal and disposal of all structures or obstructions, other than public utilities, that interfere with construction or impair the usefulness of the proposed facility.

Items requiring removal may include bridges, buildings, culverts, foundations, wells, debris, or any other man-made feature that may be encountered in the performance of the work.

It is essential that the contractor clearly understands which structures are required to be removed and salvaged, and those that are to be removed only. The contract drawings and specifications should indicate the disposition of all known obstructions.

The detail methods for demolition and removal of structures and other obstructions are not usually specified. Therefore, the inspector should restrict his activity to such items as determining compliance with safety and fire requirements, and the required salvage or disposal of all material. Salvaged material should be inventoried, delivered and stored as outlined in the contract. Entries in the Job Diary should record progress and any instructions, interpretations of the drawings or specifications, or warnings that were given to the contractor.

Inspector's Check List.

1. Determine that utilities shown on the drawings are properly identified in the field.

2. See that owners of utilities have been given adequate notice for removal or protection of utilities in the work area. Inform supervisor of any action he needs to take.

3. See that proper precautions are taken by the contractor to safeguard all utilities.

4. Advise your superior immediately if unidentified utilities or other obstructions are discovered.

5. Check contract drawings to determine that they show all structures that are to be removed or salvaged.

6. Determine that structure removal is accomplished in a manner to prevent damage to adjacent structures that are to remain in place.

7. Make sure that codes which pertain to the safety of the workmen and the public are complied with, including installation of road signs, lights and barricades.

8. Determine that all structures or other obstructions are removed to the required limits, and the materials properly disposed of.

9. That voids resulting from structure removal are backfilled as specified.

10. Record numbers or quantities and all Job Diary entries.

Site Clean-up

General.
A well organized construction project is indicated by the immediate disposal of surplus or discarded materials and debris from the work site.

A systematic clean-up is essential for efficient operation of all phases of construction within the work area and also to eliminate a potential hazard to workmen and equipment engaged on the job. The Government representative should see that the work site, and any surrounding areas used by the contractor are kept in an orderly condition at all times during the progress of the work, and that all areas are properly restored prior to acceptance of the project. The General Provisions of the Construction Contract clearly outline the requirements.

The inspector should require that:

1. All surplus or discarded items are promptly disposed of or removed from the site as the work progresses.

2. Upon completion and prior to acceptance of the work, all plant, buildings, unused material, rubbish, cleared material and debris should be completely removed and the site left in an orderly condition.

3. Trails and roadways used for ingress and egress are left in an acceptable condition, and that fences, utilities or other facilities temporarily removed during construction are restored according to the terms of the contract.

Earthwork

General.
The inspector on earthwork operations should become familiar with the lines, grades and cross sections shown on the drawings; with the specifications that control the work, and with the staking procedures used on the project.

He should also carefully review the geologic reports, the soil mechanics laboratory reports, and other data that relates to moisture and compaction control, as well as on-site exhibits such as test pits and soil profiles.

Consideration should be given to the requirements for the extent and intent of the excavations, and the recommended use of the excavated materials.

As the work progresses, he should arrange for the before and after surveys as required for computation of pay quantities.

The inspector should have knowledge of the capabilities of various types of equipment, the contractor's plan of operations, and the proposed methods of performing special items of work such as drilling, blasting and dewatering of the site.

The inspector should not attempt to dictate the methods or equipment used unless so specified in the contract. It is the contractor's prerogative to select and provide the types of equipment that he considers most efficient and economical. His choice of equipment will depend on the nature of the material being excavated, grades to be traveled, length of haul, working room, and cost and availability of equipment.

The contractor's schedule of work is of interest to the inspector. He should have access to the contractor's proposed schedule of operations at all times and should compare actual progress, informing his superior of any major deviations as to either sequence or rate of progress.

The inspector should determine that all earthwork is properly graded and drained at all times, that excavations are not carried below grade, and that excavation and embankments are properly constructed to planned line and grade.

Excavation and Foundation Preparation.

Classification and measurement.--Excavation includes the performing of all operations required to excavate earth, rock or other classifications regardless of character or sub-surface condition. Excavations should be made to the lines and grades shown on the drawings and as staked in the field. However, the inspector should be cognizant of the requirements for the excavation, especially foundations for embankments and subgrade for structures, and should recognize conditions that may require changes in extent or location. He also must recognize when rock or other latent conditions are encountered that are not provided for in the contract.

The estimated classification and amount of excavation required is summarized in the bid schedule. In some instances it is not economically feasible to determine in advance what subsurface conditions will be encountered over the entire area to be excavated. Explorations, such as borings, pits or trenches, reveal subsurface conditions only at the location investigated. Often variations are encountered within intermediate areas which differ from the classifications or amounts shown in the bid schedule.

Foundation conditions or excavated materials may be encountered that differ materially from those shown on the drawings or in the laboratory reports. The inspector should immediately inform his superior when such conditions are encountered.

Disposal of excavated materials.--Excavated materials that are suitable should be used as required within the limits of the project.

Unsuitable or surplus excavation is considered as waste material and should be disposed of at the locations and in the manner set forth in

the contract. Usually waste or surplus materials are spread in a neat uncompacted condition with proper consideration for drainage and appearance. Wet materials otherwise suitable should be stockpiled for use after drying, if so specified in the contract or approved by the Government representative. The engineer should not be hesitant to order removal and disposal of unsuitable material encountered, even though not originally planned or anticipated. This condition frequently occurs in the preparation of foundations for structures.

When required, suitable top soil should be removed to the limits of the structure and stockpiled in the locations specified.

Blasting.--Blasting is a hazardous operation; therefore, the inspector should not only check to see that the results meet the excavation requirements but, in addition, that the contractor stores, transports and handles blasting materials in accordance with the safety regulations and local governing codes.

Blasting procedures which loosen rock outside of the planned subgrade or slope lines may be objectionable. Extending the depth of holes a short distance below structure subgrade or slope is common practice to eliminate the necessity for secondary blasting. However, shooting below grade or overloading may cause serious damage to rock foundations. The inspector should check the contractor's operations by plotting depth, direction and spacing of holes on the cross sections or mathematically determine their relation to the finish grade to determine that they are not excessive in depth. Depths of drill holes should normally be limited to one (1) foot below grade. Records of amounts and strength of powder used should be kept. The notes should show typical loadings including number of sticks, kind and strength of powder and location and depth of hole, i.e., 4 sticks, 60 percent Hercules blasting powder at Sta: 3+92, 10' Rt. of centerline at 3.9' depth. These records may be important in case of excessive damage to foundations, or claims for extra work to remove materials and reslope slide areas.

Borrow Areas.

When the required excavations are not adequate to provide the planned amount of fill, it will be necessary to supply additional material from approved borrow areas. The borrow areas should be selected and approved in the design phase and their locations shown on the drawings. In some cases, the location and the furnishing of acceptable borrow may be the responsibility of the contractor. The inspector should review the contract documents relative to borrow areas and take the necessary action to inspect the sites for adequacy of clearing, removal of overburden, and the selection of suitable materials from within the designated limits. Also, he should make timely subsurface investigations to determine that adequate quantities of acceptable materials are available. In estimating quantities of available material, the relation of bank measure and compacted in-place volume must be considered. Fine-grained soils tend to increase in volume (swell) when removed and shrink when compacted. Shrinkage is expressed as a percentage of bank measure and may amount to as much as 20 percent for

some soil classifications. If the investigations indicate that the designated borrow areas are not adequate, immediate action should be taken through proper channels to locate a new source and to work out a satisfactory agreement with the contractor for preparing and hauling from the new location. When borrow materials are included as a pay item, before and after surveys will be required to determine quantities of materials excavated. All borrow areas should be drained and graded as specified in the contract.

Diversion and Control of Water.

The stability of the subgrade or foundation and its adequacy for safely supporting the design loads may be affected by the methods and equipment used for diverting streamflow or dewatering the site. It is the responsibility of the contractor to construct the necessary diversion works and provide and operate adequate equipment to maintain the foundations and structures free of all water, unless otherwise specified, when placing fill or structural improvements.

The inspector should check the adequacy of the diversions and dewatering operations and see that the project is dewatered as required to provide protection to all parts of the work.

Borrow areas which are susceptible to flooding should be managed to provide drainage or protection so that maximum utilization may be made of the material. In some instances, excavated overburden from the borrow area may be placed in temporary dikes along the edge of the borrow area to provide additional protection.

Foundation.

The success of embankment construction depends to a large degree upon proper preparation of the foundation. The presence of slippage planes, areas of soft unstable materials, and free water from springs or seeps are some of the conditions which should be watched for and corrected prior to placing the embankment. The engineer should keep in mind that embankment failure can generally be traced to:

1. The weight of the embankment displacing or consolidating the foundation material causing differential settlement.

2. Loss of stability of the embankment when the foundation becomes saturated.

3. The weight of the embankment constructed on a sidehill which may cause movement due to a slippage plane in the underlying foundation.

4. The presence of permeable strata in foundations which may cause detrimental uplift and piping.

Also, when considering foundation conditions and site preparation for an embankment, attention must be given to the abutments as well as the valley plane. The objective in foundation preparation is to secure a base for the structure, and to bond effectively the foundation and the embankment into one unit. The bond is obtained for earth by

scarifying and compacting the foundation surface after the required stripping operations have been performed.

For foundations consisting of earth and rock or gravel, ripping and rolling may not be required in the specifications.

Fat clay soils and some clay shales are subject to excessive volume change due to wetting and drying. Changes in the moisture content of such materials should be reduced to a minimum when they are exposed in foundations. This requires that the exposed surfaces of such material be covered as soon as practicable or that excavations of the final 6", or more when specified, for the foundation surface be removed just prior to the placement of embankment or other structural materials. To ensure a satisfactory foundation in these soils may require scheduling the excavation and backfill as simultaneous operations, or when this is not possible, the placing of a protective cover of plastic, asphalt, or other material.

For solid rock foundations, extra precaution should be taken to provide satisfactory bond between the foundation and the embankment. Required operations often include careful removal of earth and weathered materials from the surface and from cracks and crevices within the rock material. In addition, it may be required that the exposed rock be washed and broomed to expose a clean surface for grouting with concrete mixtures or backfilling with select earth materials. It is also extremely important that overhanging rock or other undesirable formations be removed and the foundation and abutments be sloped as specified so that intimate contact may be made between the compacted embankment and the foundation.

Under certain conditions, grouting of the subsurface area below the foundation will be required. This process consists of injecting under pressure through drill holes, suitable mixtures of cement, sand, bentonite, clay, or other materials. The purpose for using this process is to seal off all seams, cracks or fissures in the rock to form an impervious curtain. The drawings and specifications will indicate the location, depth, and materials required. Each location presents a distinct problem and changes or additions may be required as the work progresses.

The Government representative should inspect and approve all foundations prior to the placement of earth embankments or other structural material.

<u>Inspector's Check List</u>.
Stripping and foundation preparation (other than structures).--

1. Determine that limits for excavation are clearly outlined in the field.

2. See that all needed preconstruction cross sections have been taken.

3. Check depth and area of stripping and disposal of materials.

4. Examine foundation materials to determine that they conform to quality assumed for design.

5. See that all foundation depressions are properly filled.

6. Determine that adequate provisions have been made to control water, and that foundation areas are properly dewatered.

7. See that depth of scarification and other foundation preparations are complete.

8. Make sure that oversize rock are removed before compaction.

9. See that density of earth foundation, after compaction, meets the requirements.

10. Make sure that loose rock and other materials are removed from rock foundation.

11. Determine that rock surfaces are thoroughly cleaned and filled as specified.

12. See that rock surfaces are adequately moistened prior to placing grout.

13. See that foundation grout work is properly cured and protected.

Stripping and foundation preparation (for structures).--

1. Determine that excavation limits are staked to line and grade as indicated on the drawings.

2. See that necessary preconstruction cross sections for excavation are complete.

3. Compare the foundation material with description in logs of test borings.

4. Examine subgrade for smoothness, compaction and finished grade.

5. See that foundation areas are adequately dewatered - concrete should be placed in the dry, unless specified otherwise.

6. Examine construction site for adequacy of protection from surface water.

7. See that sufficient surveys are made to determine quantities.

Excavations - earth.--

1. Compare material excavated with description contained in logs of test borings.

2. Make sure that suitable materials are used in the work as specified, and that unsuitable materials are placed in designated waste areas.

3. Check moisture content of approved material prior to excavation, require drying or adding water to meet moisture limits as required in the contract.

4. Determine that excavation is performed by procedure and in sequence necessary to provide suitable materials.

5. See that adequate drainage is provided as excavation progresses.

6. Determine that operations in borrow pits are as specified and within the staked limits.

7. Require that final finish and drainage of borrow areas be as specified.

8. Be sure that adequate before and after surveys are made for quantity determination.

Excavations - rock.--

1. Check adequacy of blasting pattern - compare with test blasts before starting full scale operations.

2. Inspect handling, storage and use of explosives - note compliance with requirements of the contract and with city, county, and state regulations.

3. Before blasting begins, be sure the contractor complies with requirements for warning the public and providing protection to buildings, roads, or other fixed improvements. Radio transmission might set off a blast prematurely.

4. Secure a statement from the contractor setting out the qualifications and experience of blasting supervisor, drillers, and powdermen.

5. Check results of each blast, and insist on compliance with specified restrictions for blasting as final grades are approached.

6. Determine that excavated material is handled and used as specified.

7. Check that adequate before and after surveys are made for quantity determination.

Embankment and Backfill.

General.--The availability and quality of materials and the foundation conditions are some of the major factors in determining the type of embankment that can be economically constructed, or is practical at a given location. There are numerous refinements which may be applied in the design of embankments. In the watershed protection and flood prevention program, the primary concern is minimum cost for a safe, durable structure that will give the level of protection justified for the project. An analysis on this basis usually results in the use of earth, rock or combinations of these materials for the majority of the embankments designed for P.L. 566 projects.

When earth is the primary construction material, it is necessary to design for a greater range of tolerance in its utilization than for other construction materials, because of the inherent variation in the properties of earth materials as found in their natural state, and because of the methods used in construction. Earth used for embankment construction may range from fine-grained soils with 100 percent finer than a No. 200 sieve to stony soils containing 65 to 70 percent gravel and cobbles or mixtures of various intermediate sizes. The availability of the various kinds of soil at a site, the engineering properties of the materials and the purpose of the structure have a direct influence on the design of the embankment. Homogeneous embankments are generally designed for sites where the materials have about the same gradation and properties. Zoned embankments may be designed to utilize two or more different kinds of soil. Earth embankments constructed to impound or to control water movement require strict coordination between design and construction.

The proper use of earth as a construction material requires detail supervision and inspection similar to that required at the plant when producing other manufactured building materials. The primary difference is that for earth embankment construction the methods and procedures used to produce an acceptable building product has to be performed in the field, as the job is constructed.

Construction of earth embankments requires improving the engineering properties of the building materials by selection, moisture control, compaction, and in some instances, special processing.

For these reasons, it is important that the construction procedures do not deviate from the contract requirements. Inspection of embankment construction requires knowledge, experience, use of judgment and authority to insure complete compliance with the intent of the contract.

Embankment Construction - Earth Fill.

Material requirement.--Embankments are normally constructed from the best materials available. Those materials which are suitable and those which are not suitable for use in construction must be based on an evaluation of the physical properties which may influence the stability of the specific type of structure under consideration. The physical properties of soil materials are determined by means of well

established laboratory and field test methods. Evaluation and interpretation of the test results will determine the suitability of the material for a given site.

The "Unified Soil Classification System" developed jointly by the Corps of Engineers, U. S. Army, and the Bureau of Reclamation, U. S. Department of Interior, has been adopted by the Soil Conservation Service for use as a standard for all engineering work. Explanation of this classification system is published in Technical Memorandum 3-357, Corps of Engineers, U. S. Army, 1953. All engineers and inspectors working on construction should become familiar with the classification system outlined in this memorandum.

A soil classification system must be adequate for separating soils into groups which relates the physical properties and pertinent behavior characteristics of each group. Soil behavior characteristics which are most pertinent to the structural stability of an earth embankment are: (1) shear strength, (2) deformability, (3) resistance to piping, (4) compressibility, and (5) compactibility. For structures designed to store water, another pertinent point includes resistance to transmission of water.

Figure 3-1 illustrates the applicability of the Unified Soil Classification System to engineering construction problems. This chart was prepared by A. A. Wagner, Assistant Chief, Earth Laboratory Branch, Bureau of Reclamation, Denver, Colorado. The chart was published in connection with an article entitled, "The Use of the Unified Soil Classification System".

Figure 3-1 also shows four important properties of the soil groups, namely: permeability, when compacted; shearing strength, when compacted and saturated; compressibility, when compacted and saturated; and workability as a construction material. Based on these properties and experience, the relative desirability of the typical soils is shown for use in rolled earth dams, channel sections, and foundations. The indicated numerical ratings are intended as a guide in comparing soils for various uses. In the ratings, No. 1 is best with less desirable soil groups rated in ascending order.

As found under natural conditions, the soil groups may occur in combinations, such as GW - GC, SW - SC, etc. Some of these combinations, often referred to as boundary soils, are desirable materials for rolled fill earth dams. For example: GW - GC well graded gravel with sufficient clay fines to make the soil impervious, is an excellent material for the core and impervious section of the dam.

Test No. S-1, Chapter 4, briefly outlines methods that may be used in the field to identify and classify soils according to the Unified Soil Classification System. Figure 4-3, included in the test, indicates to some degree the suitability of the different soils for various uses in embankments and the suggested types of equipment that may be used to efficiently compact the soil classes.

Engineering Use Chart

Typical names of soil groups	Group symbols	Important properties: Permeability when compacted	Important properties: Shearing strength when compacted and saturated	Important properties: Compressibility when compacted and saturated	Important properties: Workability as a construction material	Relative desirability for various uses — Rolled earth dams: Homogeneous embankment	Rolled earth dams: Core	Rolled earth dams: Shell	Canal sections: Erosion resistance	Canal sections: Compacted earth lining	Foundations: Seepage important	Foundations: Seepage not important
Well-graded gravels, gravel-sand mixtures, little or no fines	*GW*	pervious	excellent	negligible	excellent	—	—	1	1	—	—	1
Poorly graded gravels, gravel-sand mixtures, little or no fines	*GP*	very pervious	good	negligible	good	—	—	2	2	—	—	3
Silty gravels, poorly graded gravel-sand-silt mixtures	*GM*	semi-pervious to impervious	good	negligible	good	2	4	—	4	4	1	4
Clayey gravels, poorly graded gravel-sand-clay mixtures	*GC*	impervious	good to fair	very low	good	1	1	—	3	1	2	6
Well-graded sands, gravelly sands, little or no fines	*SW*	pervious	excellent	negligible	excellent	—	—	3 if gravelly	6	—	—	2
Poorly graded sands, gravelly sands, little or no fines	*SP*	pervious	good	very low	fair	—	—	4 if gravelly	7 if gravelly	—	—	5
Silty sands, poorly graded sand-silt mixtures	*SM*	semi-pervious to impervious	good	low	fair	4	5	—	8 if gravelly	5 erosion critical	3	7
Clayey sands, poorly graded sand-clay mixtures	*SC*	impervious	good to fair	low	good	3	2	—	5	2	4	8
Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity	*ML*	semi-pervious to impervious	fair	medium	fair	6	6	—	—	6 erosion critical	6	9
Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	*CL*	impervious	fair	medium	good to fair	5	3	—	9	3	5	10
Organic silts and organic silt-clays of low plasticity	*OL*	semi-pervious to impervious	poor	medium	fair	8	8	—	—	7 erosion critical	7	11
Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	*MH*	semi-pervious to impervious	fair to poor	high	poor	9	9	—	—	—	8	12
Inorganic clays of high plasticity fat clays	*CH*	impervious	poor	high	poor	7	7	—	10	8 volume change critical	9	13
Organic clays of medium to high plasticity	*OH*	impervious	poor	high	poor	10	10	—	—	—	10	14
Peat and other highly organic soils	*Pt*	—	—	—	—	—	—	—	—	—	—	—

From: Article entitled "The Use of the Unified Soil Classification System by the Bureau of Reclamation", by A. A. Wagner, Assistant Chief, Earth Laboratory Branch, Bureau of Reclamation, Denver Federal Centre, Denver, Colorado.

Figure 3-1

Identifying soils according to the Unified Soil Classification System alone does not always provide sufficient classification information. For example, soils that contain gravel and rock particles larger than a No. 4 sieve, all have a decided influence on soil mechanics testing operations, on design, construction methods, and construction control procedures.

Gravelly and stony soils used as compacted embankment material may be classified into three groups and sub-groups on the basis of the durability of the coarse material, as follows:

Group I - Durable Materials: The coarse fraction of these soils consists of hard, durable minerals and rocks which do not break down or degrade significantly during excavation and compaction operations.

Group II - Moderately Durable Materials: The coarse fraction of these soils generally consists of low plasticity shales or other materials that will be degraded by excavating and compacting operations into aggregates that are relatively water stable and can be separated from the matrix material after compaction without significant further degradation. This type would include moderately soft to hard shales, siltstone, disintegrated granite, cherty limestone, granitic gneiss and schist, etc. The coarse material may vary in hardness from moderately soft (2+) to hard (3 or 4). Plasticity generally will be low with PI values less than 15. Dry unit weight of the coarse particles generally will be greater than 110 p.c.f. (bulk specific gravity > 1.76).

Group III - Non-Durable Materials: The coarse fraction of these soils consists of materials that will be degraded by excavating and compacting operations into aggregates that are not water stable and cannot be separated from matrix materials after compacting without further degradation. These materials degrade easily and readily during excavating and compacting operations to form a mass of matrix and gravel fragments from which it is practically impossible to separate various sized fractions. In some cases, the gravel particles are softer and less dense and, therefore, less resistant to breakdown than the matrix after compaction operations. Manipulation, sieving, and other processes of size separation results in significant breakdown of the gravel size particles. This type would include soft plastic clay shales and marls, clayey siltstones, etc. The coarse fraction generally will have hardness of 2 or less, PI values greater than 15, and dry unit weight less than 110 p.c.f. (bulk specific gravity < 1.76).

Groups I and II are divided into sub-groups (A,B,C) on the basis of the relative amount of the material that is smaller than the No. 4 sieve size.

Sub-groups based on gradation characteristics have little significance for Group III (soft, degradable) materials. The physical separation of these materials into various sizes is very difficult or impossible.

Sub-groups A, B, and C are defined as follows:

Sub-group A (Groups I-A and II-A). Soils with more than 65 percent smaller than the No. 4 sieve size.

Sub-group B (Groups I-B and II-B). Soils with 65 percent to 35 percent (inclusive) smaller than the No. 4 sieve size.

Sub-group C (Groups I-C and II-C). Soils with less than 35 percent smaller than the No. 4 sieve size.

The construction drawings and specifications represent designs which were based on laboratory tests of samples taken from the foundation and borrow areas at the structure site. It is the primary responsibility of the inspector to be able to determine (1) if the materials being placed in the embankment differ materially from the classifications which were made of the test samples, and (2) the variations in soil materials so that for zoned structures, the specified materials may be routed to the correct locations in the embankment. The inspector should notify his superior if materials from the specified sources vary materially from the test samples.

Control of materials and placement.--Control of the placement of materials in the embankment is exercised for the purpose of securing the required density and moisture in the fill, and the proper distribution within the limits of the various sections making up the embankment when a zoned fill is specified. The first requirement is met through performance of the specified tests. The second requirement is met by requiring the spreading of the materials on the fill in such a way as to secure uniformity of gradation in each zone, or a gradual transition between zones, in conformance with the requirements of the specifications and the drawings.

When moisture control and blending of materials to be placed in the embankment are accomplished at the borrow source, it is important that close inspection be given to such operations.

No fill material shall be placed until the foundation, subgrade, and/or cutoff trench has been inspected and found to conform to the requirements of the specifications and drawings. Some soils that may exist at principal spillway, core trench or other important excavation limits have a tendency to shrink and crack as the exposed surfaces dry. These dry soils should be removed or moistened and compacted before fill materials are added to prevent a zone of high permeability in a critical location. Usually the specifications will outline the required treatment for the soil condition.

The structure foundation should be dewatered as specified, while placing embankment materials. The material, as it is brought onto the

fill, should be spread in approximately horizontal loose layers not exceeding the specified depth limits. All roots, vegetative growth or other debris, including oversize rocks, which are transported onto the embankment will need to be removed. In addition, any large hard lumps or masses of soil should be pulverized by disking, harrowing, or by other means prior to compacting. The inspector should make sure that a new lift is not placed on a smooth or frozen surface or that snow, ice or frozen materials are incorporated in the fill materials.

The embankment should be maintained at approximately the same level regardless of the number of zones or types of earth material being placed, except that rock fills or filter blankets should be placed in a manner which will prevent the soil from mixing with the rock or filter materials. The top surface of the dam, at the end of the day, should be graded for drainage. A slight grade toward the upstream slope is desirable unless otherwise specified.

Moisture control.--An understanding of the moisture density relationship, as related to the compaction of soils, is of major importance to all construction personnel. Results of tests, published in 1933 by R. R. Proctor, show that the dry density of a soil (weight lbs./cu. ft.) obtained by a given compactive effort, is directly related to the amount of moisture the soil contained during compaction. Further, for each kind of soil there is a maximum density which can be obtained with a specified compactive effort and there is also a corresponding moisture content. With repeated tests, using the same compactive effort, the density of the soil increases as water is added until a certain moisture content is reached; then, as more water is added and the same compactive effort is applied, the density steadily decreases. The percentage of moisture in a soil, based on its dry weight, at which the maximum density is obtained under a given compactive effort, is the <u>optimum moisture content</u>. Maximum density is related to the compactive force; the greater the compactive force the higher the maximum density, and the lower will be the corresponding optimum moisture content. There are as many maximum densities and optimum moisture contents for a given soil as there are variations in compactive force. The curve representing this relation plotted with moisture content (percent dry weight) as abscissa and dry density (lbs./cu.ft.) as ordinate is known as the moisture density curve (see Figure 3-2). Each soil has its own characteristic compaction curve for a given compactive effort; hence, its own characteristic values for optimum moisture and maximum density. The test procedures and method for preparing the moisture density curve is outlined in Chapter 4. Similar procedure is contained in ASTM Designation D-698 and D-1557, Method A, and in AASHO Designation T-99 and T-180. The two different specifications prepared by the two organizations are similar in procedure and give equal results. However, a difference does exist between the two respective tests, i.e., D-698 and D-1557. D-698 is based on a 5.5# rammer falling 1.0 foot, 3 layers receiving 25 blows each; while D-1557 requires a 10# rammer falling 1.5 feet, 5 layers receiving 25 blows each. The compactive effort resulting from these two procedures is approximately 12,375 and 56,250 ft.lbs./cu.ft., respectively.

The inspector should become familiar with the required compactive effort specified for each portion of the work. The structure design may be based on a compactive effort differing from that attained by one of the abovementioned standard methods. He also should check the specified percent of maximum compaction that is required.

The moisture content of the fill materials, when placed as tested embankment, requires accurate control. Dry materials should be irrigated to approximate optimum moisture content at the borrow source for good uniform moisture distribution. Additional sprinkling or drying may be required on the embankment. It is of paramount importance that the moisture content be within proper range and uniformly distributed throughout the spread layer prior to compaction. Moisture distribution can be hastened by blading, disking or harrowing. Similar procedure aids in drying materials having excessive amounts of moisture. The moisture content should be controlled within the limits required in the specifications, based on field moisture determinations made from the compacted fill.

For some soil types, it is necessary to specify maximum and minimum limits for the moisture content of the fill materials at the time of placement. These limits are usually referred to as a plus or minus percentage of the optimum moisture content at maximum density, as determined by the specified testing procedure. No fill should be accepted that has been placed contrary to the moisture requirement.

Control of the proper moisture content of the embankment and backfill material is the direct responsibility of the contractor. It is quite common to have to add water to these materials on many jobs at some stage of construction. It is advantageous to the inspector to have a quick reference which he may use as a guide in estimating the amount of moisture that is required for a given soil. The graph "Water Requirements for Compaction," Figure 3-3, may be used to determine the approximate number of gallons required to be added to a cubic yard of soil to increase the moisture content to the optimum range. It is necessary to know or estimate the moisture content, optimum moisture, and dry density of the material. The example shown with the graph outlines the procedure.

Compaction.--The contract specifications or drawings will prescribe the degree of compaction or the type and performance of compaction equipment required to achieve the desired end product for all materials to be placed in the embankment or backfill. When the degree of compaction is specified, the basic material required to be considered in embankment density control tests will vary with the types of materials described under "Material Requirements." For these various kinds of materials, construction control may be specified as follows:

Group I-A. Construction control will be based upon the moisture-density relationships of that portion of the fill matrix. (Minus No. 4 or 3/4" fraction.)

The fill matrix is defined as that fraction of the fill material having a maximum size equal to that used in the compaction test method.

SCS-352 Rev. (10/58)

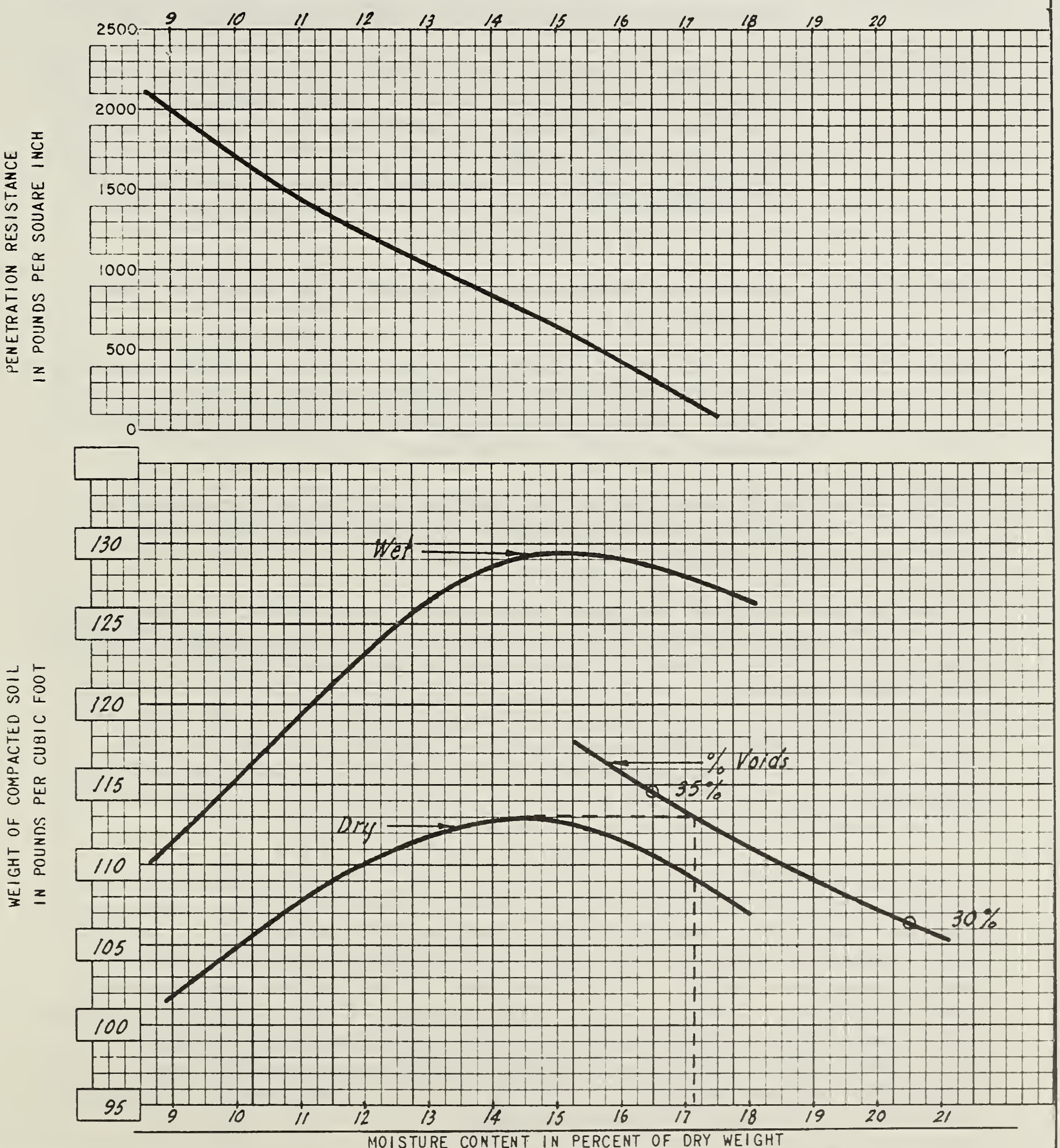
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
SOIL MECHANICS LABORATORY

COMPACTION AND PENETRATION RESISTANCE REPORT

Date 4-15-64 Sample No.: Field #1 Lab 20-64

Project Pine Creek Dam Location Site 3-A

Sample Location and Depth Test pit 63 ; Sta. 3+00-C Borrow #2 ; 2-4 ft. depth



TYPE OF TEST	TEST PROCEDURE	Classification
[X] Standard Proctor	Weight of Hammer 5.5 Lbs.	Material compacted represents 100 percent of the sample and passed #4 sieve
[ ] Modified AASHO	Drop 12 Inches	(Sp. Gr.) Gs= 2.65
[ ] Other ______	Lifts 3 layers (25 blows ea.)	Curve of
	Vol. of Cylinder 1/30 Cu.Ft.	

Figure 3-2

Group I-B. Construction control will be based upon the moisture-density relationships of that portion of the material passing the 3/4 inch sieve or upon the method of placement and compaction.

Group I-C. Construction control on this type of material will generally involve equipment and method specifications.

Groups II-A and B. Specifications for degrading materials may require control of moisture and density and/or degree of breakdown of the materials. Moisture-density control will be based upon the fraction passing the No. 4 sieve or the entire mass when it is expected that the material will break down so that 35 percent or more will pass the No. 4 sieve.

Group II-C. Method specifications will normally be used for these materials.

Group III. It is physically impossible to separate various particle sizes when these soft degrading materials have been compacted. Moisture-density control on the embankment will be based upon the entire mass.

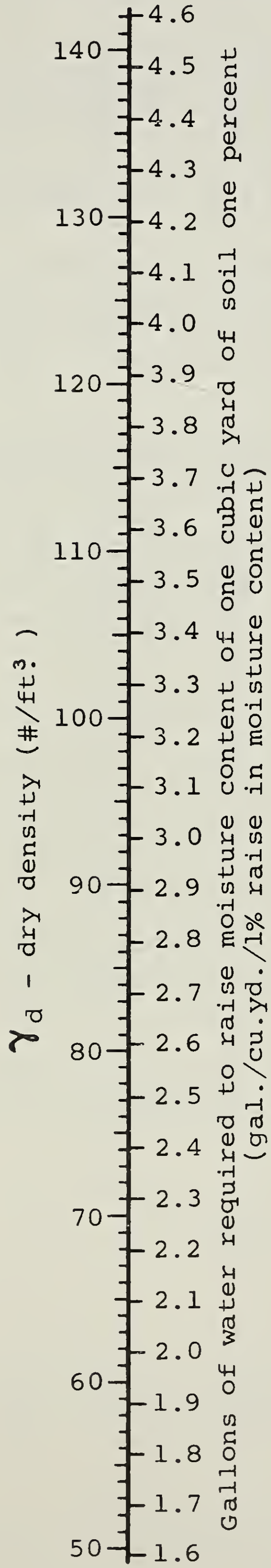
A more detailed explanation on the basic materials for tests may be found in the Service Technical Release on "The Use of Materials with More than 5 Percent Larger than No. 4 Sieve."

Unless certain methods and types of compaction equipment are specified, it is the responsibility of the contractor to get the required density throughout the total area of the spread by any means that he desires. For tested embankment the inspector should in no way attempt to control the compaction operations. However, he should require that the rolled surface has adequate moisture and is not in a smooth glazed condition at the time of receiving the next lift. The required relative compaction usually can be obtained with the least amount of effort if the moisture content is at, or near optimum.

To obtain uniform compaction of a given soil, the material should contain the required moisture and be spread in uniform lifts. Each layer must be thoroughly compacted before another lift is added. A sufficient number of trips of the compacting equipment should be made to assure complete coverage of the area and to obtain the density specified. Experience indicates that the uncompacted layer thickness should not be more than 8 inches when sheepsfoot type rolling equipment is used. Most soils compact more readily when placed in thin layers. If difficulty is experienced in securing the specified density, this procedure may aid in correcting the problem.

Figure 3-4, "Tamping Roller Data", lists some of the manufacturers of sheepsfoot type tamping rollers and includes size and weight information for various models. Detail roller data as tabulated may be used

WATER REQUIREMENTS FOR COMPACTION



This graph can be used to arrive at the gallons of water per cubic yard required to raise the moisture content of embankment materials to optimum moisture.

The density used in arriving at the water requirement should represent the density of the material at the time the water is added. (In-bank density, loose density, or compacted density.)

EXAMPLE: Material has a moisture content of 14%. Optimum moisture content is 20%. Water is to be added to material on fill. Estimated density at time water is added is 100#/ft^3. How much water will be required to raise moisture content to optimum?

From Graph: 3.24 gal./cu.yd./1% increase in moisture content where density = 100#/ft^3.

Water Required: 3.24(20-14)= 19.4 gal./cu.yd.

Figure 3-3

TAMPING ROLLER DATA

Make	Model	DRUMS				TAMPING FEET					TOTAL WEIGHT			PRESSURE		
		Type	No.	Dia. In.	Width In.	Type	Number Per Drum	Number Per Row	Length In.	Face Area Sq. In.	Empty Lbs.	Filled W/Water Lbs.	Filled W/Wet Sand Lbs.	Empty P.S.I.	Filled W/Water P.S.I.	Filled W/Wet Sand P.S.I.
BROS	M1-5-1/2	Rigid	1	40	48	Sheepsfoot	112	4	7	5.5	2,925	4,860	6,800	133	221	309
	M1-7	Rigid	1	40	48	Sheepsfoot	112	4	7	7.0	3,035	4,960	6,910	108	178	247
	M2-5-1/2	Osc.	2	40	48	Sheepsfoot	112	4	7	5.5	5,850	9,720	13,600	133	221	309
	M2-7	Osc.	2	40	48	Sheepsfoot	112	4	7	7.0	6,070	9,920	13,820	108	178	247
	G1-55-8	Rigid	1	60	60	Diamond	112	4	8	7.0	7,300	12,850	18,000	260	460	645
	G2-55-8	Osc.	2	60	60	Diamond	112	4	8	7.0	15,000	26,100	36,300	268	465	650
TAMPO	H-1	Rigid	1	40	48	Sheepsfoot	112	4	7	6.0	3,200	5,135	6,860	132	212	-
	H-2	Osc.	2	40	48	Sheepsfoot	112	4	7	6.0	6,300	10,170	13,620	132	212	-
	501	Rigid	1	60	60	Sheepsfoot	120	4	7	6.25	7,500	12,430	16,820	312	516	700
	502	Osc.	2	60	60	Sheepsfoot	120	4	7	6.25	15,000	24,860	33,640	312	516	700
	501 P	Rigid	1	60	60	Sheepsfoot	120	4	8	7.0	8,400	13,330	17,720	322	497	653
	502 R	Osc.	2	60	60	Sheepsfoot	120	4	8	7.0	16,800	26,680	35,440	322	497	653
	H 20 S	Osc.	2	40	60	Sheepsfoot	112	4	7	6.0	6,630	11,500	15,830	138	239	354
GRACE	RDX-104	Osc.	2	40	48	Sheepsfoot	104	4	7-1/8	5.5	7,100	-	-	163	248	332
	RSX-112	Osc.	2	40	48	Sheepsfoot	112	4	7-1/8	5.5	6,200	-	-	140	224	310
	TX 96	Osc.	2	40	42	Sheepsfoot	96	4	7-1/8	5.5	5,700	-	-	130	200	270
	X 112	Rigid	1	40	48	Sheepsfoot	112	4	7-1/8	5.5	3,100	-	-	144	228	314
	LXX 95	Osc.	2	60	48	Sheepsfoot	96	4	8	7.0	12,400	-	-	230	375	500
	LX5X120	Osc.	2	60	60	Sheepsfoot	120	4	8	7.0	14,250	-	-	259	455	652
	LX6X136	Osc.	2	60	72	Sheepsfoot	136	4	8	7.0	16,250	-	-	286	525	765
	LX5Y120	Osc.	2	60	60	Sheepsfoot	120	4	8	7.0	15,650	-	-	284	480	677
GEBHARD	22	Osc.	2	60	72	Square	144	4	8	6.25	21,450	33,585	-	425	635	-
	120	Osc.	2	60	60	Square	120	4	7-1/2	5.5	14,200	25,920	-	320	590	-
FERGUSON	112	Osc.	2	40	48	Sheepsfoot	112	4	7	5.5	6,340	10,200	-	150	242	-
	112 W	Osc.	2	40	48	Wedge	112	4	8	5.5	8,900	12,575	16,340	202	286	371
	112 W 48	Osc.	2	48	48	Wedge	112	4	8	5.5	9,700	14,880	20,792	220	338	472
SHOVEL SUPPLY CO.	B S 2	Osc.	2	60	60	Round	120	2	10	7.06	28,500	37,860	47,400	1,010	1,340	1,678
SLUSSER-MCLEAN	-	Rigid	1	40	48	Square	112	4	7	6.0	3,000	4,935	-	125	206	-
	-	Osc.	2	40	48	Square	112	4	7	6.0	6,000	9,870	-	125	206	-
LE TOURNEAU-WESTINGHOUSE	120	Osc.	2	60	60	Round	120	2	8-3/4	7.07	17,700	29,360	40,070	626	1,035	1,420
	W-1	Rigid	1	42	48	Round	88	4	8	5.06	3,220	5,320	6,920	158	262	341
	W-2	Osc.	2	42	48	Round	88	4	8	5.06	6,040	10,240	13,440	149	254	333
SERVIS	RS	Osc.	2	40	48	Sheepsfoot	96	4	7	5.5	5,100	9,050	12,140	116	205	276

Figure 3-4

by the inspectors to complete the required reports for the placement of compacted earch fills.

Portions of the embankment that are not accessible to heavy rollers should be compacted by manually directed mechanical tampers or other approved equipment. In these areas the thickness of lift should be reduced to about 3 to 4 inches. The specified degree of compaction should be obtained for all areas regardless of the method, or type of equipment used.

After a temporary or seasonal shutdown, the moisture and density conditons of the top lifts of a partial fill should be carefully checked prior to starting operations. Removal or recondition of the existing fill should be satisfactorily performed prior to placing new material.

Density determinations.--In place densities of compacted fill are determined by field test procedures. Acceptable methods are outlined in Chapter 4, Tests Nos. S-2, S-3, S-4, or S-5. The acceptability of the in place density is determined by comparison with the density attained by the specified compaction test, which may be performed in a laboratory on the job. The acceptable in place fill density is usually specified as a percentage of the unit dry weight resulting from this laboratory determination.

It is essential that the inspector be competent to determine that the materials placed in the fill are representative of the soils tested in the laboratory for use in the design of the structure. This determination requires careful classification of the fill materials and the making of field moisture-density tests of these materials during construction. There are areas, but not too many, where soil classification alone will confirm duplication of the materials tested in the laboratory for design, and those used on the job. Generally, the sources for embankment material vary to such a degree that it is necessary to make frequent job moisture-density curves to use for control of the contract. It is especially important that the inspector inform his superior without delay when the moisture-density results deviate from the design values so that the required corrective action may be taken.

Results of all field moisture-density determinations should be plotted on the control curve being used to determine the need for preparing a new curve.

A rapid procedure for determining relative compaction for use in the field laboratory is outlined in Chapter 4, Test No. S-6. The results of the field density tests made on the compacted fill should at all times equal or exceed the values cited in the specifications.

Frequent density tests should be taken of the in place fill at the start of a job so that the Government representative and the inspector can become experienced in judging the behavior of the materials and their reaction to the compacting equipment being used. Knowledge gained from tests may make it possible to judge quite accurately the

adequacy of the moisture content and compaction by observing the performance of the compaction equipment operating on the fill.

It is not practical to prescribe a set rule for the number of field tests to be made. This is largely a matter of judgment and will have to be determined by the state engineer, Government representative, and the inspector, based on the contractor's operations and the test results obtained. It is desirable for the state engineer at the start of the work to assist the field staff in outlining the minimum moisture and density tests that will be required for the various zones and locations on the project. The actual moisture and density tests are the only records that exist on which to base acceptable performance of the contract. Therefore, it is suggested that in no case should the frequency be less than one test for each 2,000 cu. yds. of impervious zone material placed and a minimum of one test for each shift. More frequent tests may be required depending on height of embankment, type of fill material and operating conditions. Tests should be taken in locations where mechanical hand tampers are used as well as on the areas covered by heavy compaction equipment. Extra tests should be made on the embankment placed around principal spillway structures, in cut-off trench backfill and any other difficult or critical areas that exist on the job.

The responsible engineer should review the density and moisture tests to determine that the day-to-day testing program is adequate to ensure uniformity and a safe structure.

The inspector must be alert at all times to detect areas of low density. Portions of the fill which do not meet the specified density must be corrected by: (1) removing and replacing, (2) scarifying correcting moisture content and re-compacting, or (3) additional rolling as required.

Possible locations where insufficient compaction may occur include the following:

1. The junction between mechanical tamping and rolled embankment along abutments, pipe conduits, risers, or other restricted locations.

2. Areas where rollers turn during compacting operations.

3. Areas where too thick a layer may have been compacted.

4. Areas where improper moisture content exists in the material.

5. Areas where it is suspected that less than the specified number of roller passes were made.

6. Areas where dirt-clogged rollers are being used to compact the materials.

7. Areas where oversize rock, which has been overlooked, is contained in the fill.

8. Areas where materials have been placed that contained minor amounts of frost, or at nearly freezing temperatures.

9. Areas that were compacted by rollers that have lost part of their ballast.

10. Areas containing materials differing substantially from the average.

Accurate locations should be recorded for each field test. The location and number of each test should be spotted on plan and profile drawings of the structure to aid in securing a representative sampling of the total embankment.

If a test indicates that the fill does not meet specifications, at least one additional check test should be made within close proximity, to verify the results of the first test. In no case should the contractor be required to remove or rework a lift until the limits of the unsatisfactory density have been defined. Tests are also required of the reworked material to determine that the compaction is satisfactory.

Complete documentation should be made of the tests, including locations in the embankment, and procedures required for correction. SCS Form Nos. 530A or 530B may be used for documenting the tests. Entries should also be made in the Job Diary of unsatisfactory tests, citing the number of the density test, the compaction obtained, and the necessary corrective action taken to construct the fill to required density.

<u>Embankment Construction - Coarse Grain Soils</u>.
Coarse-grained soils are materials which contain a large percentage of gravels and cobbles. Compaction control by conventional laboratory tests of these soils is an uncertain if not impossible task. When this material is specified for use in embankments it is necessary to use control methods differing from those employed when using fine-grained soils.

The portions of the structure where coarse-grained soils are to be used will be shown on the drawings. Care should be taken to confine the placement of these materials in the specified area during construction because use in other sections may affect the strength and performance of the resultant earthfill.

Usually, in addition to the location for placing these materials, the following requirements will be specified:

1. The maximum thickness of uncompacted layers or compacted layers.

2. The maximum size rock that can be included in the layers.

3. The method of compaction. Usually the number of passes of a specified type and weight of roller or tamper.

4. There may be limits on the moisture content for compaction.

Precautions should be taken to provide thorough mixing of the materials. This will provide distribution of fines through the mass and prevent pockets of fines and large cobbles.

When there is a variation in gradation of the fill material, the placing should be controlled so that no pockets or lifts of coarse-grained materials are placed adjacent to or within relatively impervious zones except as specified in the contract.

The moisture content of coarse-grained soil may or may not be critical depending upon the type of fines in the material. When the fines are noncohesive, excessive moisture will have little effect on compaction. Usually this type of material may be consolidated best when dry or completely saturated. Sands placed at certain low moisture content often tend to bulk. This condition can seriously affect the density if vibratory equipment is not used for compaction. When the fines are plastic, the material will usually compact best when the moisture is limited to about 2 percent above optimum moisture for minus 4 material.

When no density is specified, the compaction is controlled by the method of placement. Occasional large size density tests may be required to insure that the method of compaction used is producing the desired density. The density samples should be in the range of 10 cubic feet in size to give reliable results.

Embankment Construction - Rock.
Rock embankments will be considered as those consisting of materials which do not have sufficient fine fractions to fill the interstices of the rock. This will generally include gravelly and rocky materials with less than 35 percent passing the No. 4 sieve. Both Types I and II - Durable and Moderately Durable Rock - may be used for rock embankments.

Rock material used for the construction of embankments or zones within embankments should meet all of the requirements of the specifications including gradation, maximum size, specific gravity and percentage of fines. Likewise, the location within the embankment and the thickness of spread will be governed by the requirements of the drawings and specifications. Usually the maximum thickness of spread before compaction is equal or slightly in excess of the maximum size rock specified.

Materials usually are dumped on the compacted lift and then uniformly spread with dozers or other approved equipment. It is important that adequate spalls or sand gravel materials are available to fill the large interstices of the rock. Large stones should not be allowed to be placed in clusters or nests. Equipment for compaction should be checked to see that the requirements are met. Track type tractors supplemented with roller equipment, such as grid, pneumatic or vibrators are effective compaction units. On large jobs and where adequate supplies of water may be made available, the use of high pressure jets may be used to sluice spall materials into the openings. The water also

removes the soil fines and provides clean contact between the rock particles for added stability. The specifications may also require applications of water to each lift to satisfactorily wet the surfaces of the rock prior to compaction. Under normal procedure, rock fills are accepted as the result of meeting prescribed methods of placement. Rock placed in conjunction with earth or filter zones should be carefully regulated in elevation so that the earth and rock materials are not permitted to become intermixed. Maintaining at least one foot differential in elevation between the various zones will help to prevent mixing of the materials.

Embankment Construction - Test Fills.
One of the major problems in the use of durable or degradable gravelly and rocky soils for embankments concerns difficulties and uncertainties in setting up laboratory test specimens that will duplicate conditions of materials after placement and compaction in the embankment.

Test fills provide the most practical means of establishing compaction requirements for these materials.

The construction of test fills can be handled in two ways:

1. The preferred procedure is to build the test fill at the time the site is being investigated. Laboratory tests and design values can then be set up with some assurance that the product tested can be duplicated on the fill with certain equipment performance.

2. The alternative is to build the test fill at the time of construction. In this case, certain material conditions have been assumed in the testing program and contract modifications may be required if properties of the test fill do not match the assumptions made for design.

Test fills may be needed to provide realistic design values and construction control specifications for the following conditions:

A. Soils with more than 35 percent hard durable rock larger than No. 4 sieve. (Groups I-B and C - coarse-grained soil).

   Mass density will quite often be the basis for compaction control of these materials. The mass density will vary with the amount, size and shape of rock particles, with the plasticity of the matrix material, and with the compactive effort applied. The size of rock in materials to be used often exceeds the maximum size that can be tested in the laboratory. Theoretical adjustments in density to take care of oversized rock often result in density specifications that are difficult to obtain on the embankment. Test fills provide a realistic basis for design and construction control.

B. Soils with shale, sandstone and other degradable materials larger than No. 4 sieve after compaction. (Groups II and III - coarse-grained soils.)

Test fills are almost mandatory in preparing specifications for use of these materials.

The density of these materials varies with the amount of breakdown or degradation that can be achieved with specific equipment performance. The shear strength and permeability are also dependent upon the amount of breakdown achieved. There is presently no way in the laboratory to predict the breakdown and ultimate density of these materials without some previous knowledge of behavior of materials when treated in a specified manner.

The construction and evaluation of test fills prior to testing and design are especially important when degradable materials make up an important part of embankment construction materials.

Procedures for constructing test fills will be as required in the contract. The following suggested guides are pertinent to the operation:

1. Material placed in the test fill should be taken from proposed borrow sources. If this is not possible, as in the case of deep emergency spillway cuts, material should come from identical deposits that are exposed and available.

2. Whenever possible, test fills should be constructed in locations that may be incorporated into the final embankment.

3. The test fill should be at least 2 feet above starting elevation before the testing and records program is started. When placed on soft foundations, the test fill should be at least 4 feet above starting elevation before the testing program is started.

4. Test sections should be at least 30 feet wide and 200 feet long in order to provide realistic space for placement and rolling.

5. Testing and evaluating test fills will ordinarily involve:

    a. Determination of gradation of materials before and after compaction.

    b. Determination of in place dry density on the mass or other specified fraction.

    c. Detailed records on type and kind of processing and compacting equipment used, number of passes, lift thickness before and after compaction, equipment performance, wetting or drying operations, borrow excavation operations.

    d. Undisturbed cores or hand-cut samples for laboratory tests should be collected from test fills of shales, sandstones, or other degrading materials.

6. All tests pertaining to the final product at a specific location should be referenced to the same immediate area and elevation, i.e., gradation samples before and after compaction, the in place density test, and the core sample should all be taken as close to the same station and elevation as possible.

7. At least four locations should be tested for each change in material or variance in type or performance of equipment. Test areas should not be located within 5 feet of the outside or 25 feet of the end boundaries of the test fill.

8. Sampling and testing should generally be done in lifts below the immediate surface lift.

9. Tests should be conducted in at least three separate lifts of material. With 6-inch compacted lifts, this would mean a minimum fill height requirement of 4 feet for firm foundations and 6 feet for soft foundations.

Backfill.

Backfill is the placement of various types of earthfill as required for the installation of concrete structures, pipe lines, culverts or other structural work.

The required quality of materials, moisture control and compaction is usually specified in a similar manner to the requirements for the placement of embankments. The specifications will be based on design criteria, influenced by the site conditions and the functional performance of the structure.

Backfill materials, insofar as possible, are supplied from the required excavations or specified borrow areas.

Backfill requiring density control should be tested in the same manner as prescribed for compacted embankments. Cohesionless free drainage materials are usually placed according to a procedural requirement and do not require testing.

The inspector should recognize the importance of placing backfill in accordance with the drawings and specifications. In general, the control techniques outlined previously in this section for embankments, including records and reports, apply to backfill. Compacted backfill placed to meet specified density requires careful inspection of materials, amount and uniformity of moisture, gradation, layer thickness and density. All backfill should be placed to the lines and grades shown on the drawings.

Backfill operations around and over structures require that the contractor conform to the time limitations for loading called for in the specifications.

Finishing.
Embankment and cut slopes are to be dressed to the lines and grades specified or staked in the field. All cut and fill surfaces should be smooth and pleasing in appearance. All objectionable stones, roots and other debris should be removed from the site or disposed of as required.

When specified, top soil should be spread as a top dressing on the embankment and cut slopes to provide a seedbed for vegetation. More favorable bonding of the material on embankment slopes is obtained when the top soil is placed in conjunction with the embankment construction rather than when it is applied over the finished fill. Often the specifications will require this procedure.

Inspector's Check List.
Embankments and backfill.--

1. Make sure adequate before and after surveys for quantity determinations have been made.

2. See that stakes are properly set and marked for embankment construction.

3. See that required excavations are to proper limits and that site is dewatered prior to placing fill materials.

4. Make sure the contractor abides by specified restrictions for haul road locations.

5. Determine that materials used in haul road construction, which will become a part of the embankment, meets all the embankment specifications.

6. See that access haul ramps are of sufficient height to prevent uneven compaction of the embankment slopes.

7. See that the fill materials are blended properly and placed within the zone limits as specified.

8. See that embankment and subgrade is free from frozen material and prevent placing earthfill containing frozen materials.

9. Make sure that the thickness of the loose lift is within specified limits.

10. Determine need for wetting, drying or mixing of fill material to satisfy moisture requirement.

11. Make sure the surface of the foundation or embankment is in proper condition before placing the next lift.

12. See that oversize stone, roots, or other objectionable materials are removed from the lift prior to compaction.

13. See that the surface of the embankment is maintained in an approximate horizontal plane but sloped sufficiently to provide drainage.

14. Make sure that field tests are made as required and that moisture content and density of fill meets the specifications.

15. Determine that moisture-density control curves are representative of materials being placed and that curves represent proper compactive effort.

16. Check grade and cross section of embankments during construction.

17. Determine that structure foundations are compacted uniformly and are to grade.

18. Do not permit backfill around concrete structures until the time limit or minimum strength test of concrete is met.

19. Make sure that the placement and compaction of the backfill around and over structures meets specifications. This can be a critical operation. Include the required density tests.

20. See that rock or other coarse-grained fill materials meets the requirements for gradation and quality.

21. Check that equipment and methods used for placing rock zones meet specifications, lifts are within required limits, and size of materials well distributed.

22. See that top soil meets the requirements and is spread to the thickness and locations required. Make sure surfaces to receive top soil are scarified as required.

23. Make sure that clean up is complete, and the construction areas are graded and smoothed to present a satisfactory appearance.

24. Record all tests, quantities and Job Diary entries.

Concrete Construction

General.
Concrete as a construction material is suited for and commonly used in a wide variety of structures. Since the quality of concrete depends to a large degree on the workmanship in construction, the need for competent inspection throughout all phases of the concreting operation is of major importance. The size of the job is not a true index to the requirements. Actually, some small jobs require much closer inspection than certain projects of great magnitude.

Many excellent publications relating to concrete design, manufacture and placement are available. Any attempt to cover the complete subject in this handbook would be out of the question. Therefore, more detailed discussion will be confined to the various phases of inspection

as it pertains to actual construction procedures. More detailed information on design, tests and inspection of concrete construction is contained in the "A.C.I. Manual of Concrete Inspection", American Concrete Institute; "Design and Control of Concrete Mixtures", Portland Cement Association; and "Concrete Manual", U. S. Bureau of Reclamation. These publications are recommended for study and reference. They are readily available, and in many locations are a part of the existing construction project library.

Job Requirement.

The contract drawings and specifications will designate the class or compressive strength of concrete required, the admixtures required, the procedure for establishing quality of materials, and the control of the mix.

The general requirements of concrete are: strength, uniformity, durability, water tightness, and resistance to wear, weather and other destructive agents. All of these points are considered in the design stage. The requirements are satisfied by careful selection, proportioning and gradation of the aggregates, control of water-cement ratio, and close inspection to assure proper methods of mixing, placing and curing.

Concrete construction can be classified under three general types: namely, formed work, slabs, or mass concrete. The general requirements for quality in formed concrete are often complicated by the limited space into which the concrete must be placed, and usually by further restrictions imposed by the reinforcing steel. Except for exposed areas, any surface treatment must be deferred until the forms are removed. It is, therefore, extremely important that the concrete be properly vibrated and spaded to provide a dense smooth surface, free of honeycomb. In the case of slab construction, there may be large exposed areas which must be finished and properly protected when the concrete is placed. The special problems with mass formed concrete are the control of temperature caused by heat of hydration and the securing of suitable bond between consecutive lifts of concrete.

Control of Mix Proportions.

Water-Cement Ratio.--Concrete consists essentially of a mass of relatively inert aggregates bound together by a hardened paste consisting of chemically active cement and water. The strength of concrete is largely dependent on the quality of the cement and water paste which holds the aggregate particles together. When the paste is thinned by an excessive amount of water, the strength and resistance of the concrete is reduced. Consequently, the water-cement ratio is the most critical factor in the selection and control of concrete mixes. The mix is generally designed with the minimum water-cement ratio consistent with the project requirements. Inspectors must guard against the introduction of excess water from any source into the mix.

Workability.--Another basic consideration in the control of mix proportions is workability of the concrete. Workability may be defined as a measure of the ease with which the ingredients may be mixed into

concrete, placed, and consolidated with minimum loss of uniformity. A workable mix should be of uniform character and have a plastic consistency. The required workability depends upon the intended use of the concrete and the physical spacing of the forms and reinforcing steel. A slump test, using fresh mixed concrete, is the usual measure of workability. Well-graded aggregates, entrained air and certain admixtures increase workability. Inspectors should work the fresh concrete with a trowel to get the feel of the mix. Two different mixes having the same slump may have contrasting workabilities. One may be more plastic and show far less tendency to segregate during handling. A change in water content or gradation of aggregates, especially fineness of the sand often affects workability. The inspector should be alert to detect such variations and take remedial action if workability becomes a problem.

Aggregates.--The fine and coarse aggregates account for from two-thirds to three-quarters of the volume of concrete and their characteristics have important influences on the proportions to be used. The aggregates should be clean, hard, durable and uniformly graded material. The maximum size of coarse aggregate has important bearing on relative proportions, workability, economy, porosity and shrinkage. The amount of mortar and paste required for a given quality is reduced as the maximum size of aggregate increases. In form work of the type commonly used on water retarding structures, walls, and other members are relatively thin. Consequently, maximum size of aggregate is generally limited to one and one-half ($1\frac{1}{2}$) inch diameter. A common rule limits the maximum size of aggregates to 1/5 the minimum dimension of the member or 3/4 the clear spacing between the reinforcing bars and the forms.

Job mixes.--The specifications will prescribe whether the job mix will be established by the engineer or will be the responsibility of the contractor to furnish concrete meeting the specified strength and consistency.

When the engineer is responsible for the job mix, he should make determinations based on representative samples of the ingredients that the contractor proposes to use in the work. The mix should be designed by recognized engineering procedures, giving consideration to all the required qualities for the work, especially strength, consistency, workability and economy.

Trial mixes and sample test cylinders may be required to establish an acceptable job mix. When large aggregate producing and mixing plants, which have good quality control, are involved it may be possible to select a satisfactory job mix from the current mix and test data available at the plant.

When the contractor is responsible for the job mix, he will normally be required to submit the mix proportions which he intends to use based on tests made on representative samples of the materials. The contractor should support his recommendations with laboratory reports showing the 28-day compressive strength of the concrete produced by

the mix. The engineer should carefully check all the data prior to approving the materials and the proportions for the mix. Special attention should be given to the slump of the test mix. It is not uncommon for the laboratory results to be based on a slump test that approaches or is below the minimum slump specified for the work. The inspector should insist on satisfactory evidence that the mix will produce concrete of the specified quality when the mix has the maximum allowable slump.

The contractor should recognize that when he is required to produce strength concrete there is a chance for variation in the strength of respective test cylinders. To protect against the variance from the average, he should be encouraged to select a mix that will provide an extra margin of strength so that the average for all tests for the work will meet the contract requirements. The extra cost for providing additonal strength of 15 to 20 percent is a rather minor item to provide the necessary insurance for acceptable work.

Regardless of who designs the mix, the inspector must be alert to detect any deviation from the approved mix as it may be reflected in the concrete delivered on the job.

Inspection and Testing of Materials.

General.--It is the responsibility of the Government representative to determine that all contract requirements regarding the testing and approval of concrete materials have been completed, and that satisfactory control of the materials are assured, including the batching, mixing, and other items of manufacture.

Materials should be inspected frequently to see that they meet requirements. The specifications should be explicit in defining the standard tests that apply. The actual testing of manufactured products, such as cement, admixtures and steel reinforcement, may not be required provided the manufacturer or supplier furnishes properly documented evidence certifying that the materials furnished for the specific job meet the specifications. It is very important that the certificates be received in advance of the use of the product. Any omissions or irregularities in the certificates may justify the taking of samples for detail tests of the product before permitting its use in the work.

Requirements for inspection and testing of concrete materials are as follows:

Cement.--All cement must meet the requirements set forth in the Contract Specifications. The standard reference specifications cover five (5) types of cement:

Type I - Standard Portland cement, which is ordinarily available and used in general construction where no special properties of other types are required.

Type II - Modified Portland cement, for use in concrete construction exposed to moderate sulphate action or where moderate heat of hydration is required. Its content of tricalcium aluminate (C_3A) should not exceed 8 percent under any condition and for some contracts this amount may be reduced.

Type III - High early strength Portland cement, for use where high strengths are required at an early date, or in cold weather to reduce heating period. This may be a finer grind and contain increased amounts of tricalcium silicote (C_3S) or C_3A.

Type IV - Low heat Portland cement, for use where amount and rate of heat generation must be kept to a minimum. Not generally suited for Service concrete construction.

Type V - High sulphate resistant Portland cement, used in concrete exposed to severe sulphate action. Has a very low content of C_3A, usually less than 5 percent. Not specified for Service work except under extreme conditions.

The suffix "A" when added to Types I, II, and III designates that an air-entraining agent has been added to the Portland cement.

If more than one type of cement is required, the inspector should make sure that each type is used only for the parts of the work for which it is specified. Although testing of cement may not be required, where satisfactory certifications are obtained, the material should be inspected to determine that it has not been contaminated, or damaged by moisture.

Aggregates.--The determination that the concrete aggregates furnished throughout the job meet the specifications requires constant vigilance on the part of the inspector. Sampling, testing and grading of the concrete aggregate must conform to the detail requirements set forth in the contract specifications.

It is essential that samples selected for testing be representative of the materials used on the job. See Test No. C-8, Chapter 4, for sampling procedures. The specifications may require that the contractor furnish samples of the aggregates he proposes to use well in advance of the start of work so that necessary tests can be made. Before acceptance or rejection of the material, verification should be made that the aggregate samples were representative of the source of supply that is proposed for use. A more desirable procedure would be for the inspector and the contractor to obtain the sample jointly. They may even desire to split the sample and have comparative tests made by separate laboratories. When the material has been accepted as meeting specifications, no change in the source or gradation should be permitted unless approved by the engineer and authorized by the contracting officer.

Water.--Water used in mixing concrete should be free from injurious amounts of sewage, oil, acid, alkali, salts, silt or organic matter when tested by the procedures outlined in the specifications. Normally the available water supply will not be a problem. In case of doubt, samples should be submitted to a recognized laboratory for tests prior to the approval of the water supply for concrete manufacture.

Admixtures.--Any materials other than cement, aggregates and water that are incorporated into a concrete mix are called admixtures. Such agents may be used to increase workability, accelerate or retard hardening, improve water tightness, reduce water requirements, or expedite curing. The inspector must make sure that admixtures are used only when specified or authorized, and that only specified or approved materials are used. He should determine that the admixture is received in good condition and is correctly stored, handled, measured and introduced into the mix as required by the specifications or the manufacturer's recommendations. Because small quantities are generally involved, close control is required to attain the desired results.

The use of an air-entraining agent may reduce the amount of water needed. To maintain the design strength, it is best that the sand and water content be reduced by an amount proportionate to the volume of air entrained. No reduction should be permitted in the cement proportion. When used as an admixture, air-entraining agents should be added in solution with the mixing water.

Air-entraining admixtures should meet the requirements outlined in the contract specifications. Necessary tests of the concrete delivered to the forms should be made to determine that the air content of air-entrained concrete is within the specified limits. Tests No. C-5 and C-6, Chapter 4, outline procedures for field testing.

Other admixtures should be used only when required by the project specifications and compliance of the admixture with the specifications should be established to the satisfaction of the engineer prior to its use. When such admixtures have been approved for use, the inspector will ascertain the methods and quantities to be used, and any special techniques involved in mixing and placing. He then must insist on rigid compliance by the contractor with the required procedure.

Curing compound.--When provided for in the contract a curing compound sprayed on the concrete surface may be accepted as a satisfactory means of retarding or preventing evaporization of the mixing water.

The curing compound should conform to all the requirements contained in the project specifications. A white pigmented type compound reflects more heat and is preferred. All curing compounds should be delivered to the site of the work in the original sealed container bearing the name of the manufacturer, the brand name and the batch number. The material should be stored to prevent damage to the containers, and water-emulsion types should be protected from freezing.

Expansion joint material.--Expansion joint materials for concrete should conform to the specification and test requirements outlined in the contract documents for the job. Extra precaution should be exercised in handling and storage to prevent damage.

Water stops.--Materials for water stops should meet the quality required in the contract. Rubber or synthetic compounds should be stored to prevent contact with the sun or exposure to freezing temperatures.

Inspection Before Concreting.

Foundation (subgrade).--The procedures necessary for satisfactory preparation of foundation surfaces upon or against which concrete is to be placed are governed by design requirements and by the type and condition of the foundation material. The detail requirements included in the project drawings and specifications should be carefully executed.

(1) Rock - The surface of rock subgrade should be sound, completely exposed and dressed to a fairly uniform surface. Often the contract provides for overexcavation with backfill of earth or granular bedding material to design subgrade elevation. Inspection should check for high points in rock and acceptable consolidation and finish of the bedding material.

When it is necessary to provide bond with the rock foundation, the surface of the rock should be completely exposed and free from areas above the required subgrade elevation. The rock surfaces should be prepared by thorough cleaning. Unless otherwise specified, loose and drummy rock, flaky and scaly coatings, organic deposits and other foreign material should be removed. Cleaning may require the use of stiff brooms, picks, sandblasting, high velocity water and air jets, or other effective means.

(2) Earth - Earth foundations should be cut to grade and uniformly compacted to the degree specified. Subgrade for concrete should be damp but not wet when concrete is placed. Moisture penetration into subgrade should not be less than 2 inches.

(3) Porous Under-Drains - Porous under-drains are constructed of sand and gravel or crushed rock and gravel, suitably sized and graded to provide proper drainage, and to reduce the possibility of upheavel from frost action. The inspector should determine that the materials meet all the requirements of the specifications. Waterproof materials may be required to be placed over gravel subgrade to prevent mortar from contaminating the filter material. Placement, including consolidation and surface finish should be checked as the work progresses to ensure acceptable performance.

Inspector's Check List - Foundation Preparation:

1. Make sure the surface for concrete subgrade conforms to the specified location, dimension and grade.

2. Check the subgrade and any backfill to see that it is properly compacted. In case of overexcavation, see that backfill is made with suitable materials compacted to specified densities.

3. Determine that the foundation excavation is free from frost, ice, mud or water, and that sufficient water has been added to moisten dry subgrade.

4. See that the filter material, when required, is properly placed.

5. See that building paper or other seal materials have been placed over porous foundation as specified.

6. If foundation is on rock, see that rock is sound, completely exposed, clean and graded to a fairly uniform surface.

7. Check all adjacent concrete surfaces for cleanliness and for proper bond condition. All laitance should be removed.

Forms.

Forms for concrete structures should be tight, rigid and strong enough to sustain the weight of the concrete and any additional loads caused by men and equipment during placing. If the forms are not tight, there will be a loss of mortar which may result in honeycomb, or a loss of water which may cause sand streaking. Forms should be placed to the alignment and grade specified, be adequately braced on the outside, and the required spacers and form ties installed to maintain true alignment during the concreting operation. See Figure 3-5 for suggested form design, anchorage, and tie spacing. For hand spading, the tie spacing data may be designed for a reduced rate of pour.

A common blemish on formed concrete surfaces is the offset often found at horizontal construction joints where the forms have spread a fraction of an inch at the bottom of a new lift. These offsets can be prevented by setting the forms against the sides of the previous lift near its top surface, and securing them in tight contact by using an ample number of form ties within a few inches of the construction joint.

The contact surfaces of forms should be smooth, mortar tight, and free of holes and joints. If metal forms are used, the surfaces should be clean but should not be abraded to a bright finish. The sheathing, studs and wales used in the forms should be of proper dimensions and spacing to withstand the hydrostatic pressure exerted by the fresh concrete. Before concrete is placed, the form surfaces should be wetted, oiled or coated with satisfactory nonstaining materials, as required in the specifications. Care must be exercised that oil is not permitted to get on construction joint surfaces or on reinforcing bars.

SPACING DATA FOR FORM LUMBER AND FORM TIES

FORM DESIGN AND CONCRETE PRESSURES

TYPES OF FORMS: An analysis of the character of the project, its location, the materials available, possible reuses of forms and cost of erection will determine the type of form to be used. Consideration must be given also to the class of work involved which may vary from walls to be back filled to those requiring an architectural finish. If conditions warrant the use of form panels, their dimensions and design will be governed by the proposed method of erection—whether they are to be put in place by hand or with a crane.

SIZES OF FORM LUMBER: The selection of proper sizes of sheathing, studs and wales requires consideration—first, of the maximum concrete pressure loads as determined by the factors outlined below. With these maximum pressures determined, maximum safe spacings of the most commonly used sizes of form lumber and safe spacings of ties are readily available in the tables on this sheet. With this data at hand, the most economical sizes of form lumber —both as to original cost and the cost of erection—can be selected.

It should be kept in mind that very rapid placing of concrete at a low cost per yard will require heavier forms and stronger ties to contain it at an increase in the cost of forms, and that light forms of lower cost prohibit fast pouring. A balance between cost of forms and cost of placing concrete should be worked out to arrive at the most economical compromise as to the rate of pour and strength of forms.

CONCRETE PRESSURES: Many tests have been conducted regarding this basic phase of form design. In a recent bulletin, the ACI Committee 622 has summarized these tests and the form pressures contained herein are based on this report. The main factors governing the form pressures are:

A—The rate of pour in feet of height per hour.

The rate of pour is determined by the volume of concrete to be contained in the forms and the capacity of the concrete plant, or the rate of delivery of ready mixed concrete.

B- Temperature at time of pouring concrete.

The temperature at the time of pouring concrete determines its setting rate and therefore the height of the liquid head. For practical purposes, these tables have been worked out on the basis of 50° as winter pouring temperature and 70° for summer. Heated water and aggregates have not been taken into consideration.

C—Method of placing; by internal vibrating or hand spading.

Internal mechanically vibrated concrete pressure has been generally taken to be approximately 15% higher than hand spaded concrete. If hand spading is used the increased spacings can be determined by using the table that is one foot per hour less than your actual pouring rate.

ALLOWABLE STRESSES IN FORM LUMBER: The data in these tables are based on the use of No. 1 Southern Pine, Douglas Fir (coast region), or equal. Safe fibre stress is taken as 1,800 lbs. per square inch, and deflection is limited to 1/270 of the span. Horizontal shear has not been considered because of short term loading conditions. Sheathing, plywood, studs and wales are treated as continuous over three or more supports.

FORM TIES: Types and capacities of Superior form ties and clamps and their relationship to sizes of form lumber are given on the left opposite page.

SPACING TABLES: The following tables give maximum safe spacings for the most commonly used combinations of form lumber and ties. Vertical spacing of wales depends only on size and spacing of studs and is not affected by capacity of ties. The horizontal spacing of ties on wales is governed by strength (size) of wale and/or capacity of ties.

At fast rates of pour, the wale and tie spacing may be increased for the few top wales above the point of maximum pressure, although this is not always economical.

CONCRETE PRESSURE PER SQ. FT. OF FORM*

RATE OF POUR FT. OF HEIGHT PER HOUR	2 Ft.	3 Ft.	4 Ft.	5 Ft.	6 Ft.	8 Ft.	10 Ft.
MAX. PRESSURE PER SQ. FT. AT 50° TEMP.	520 lbs	690 lbs	860 lbs	1,030 lbs	1,210 lbs	1,470 lbs	1,580 lbs
MAX. PRESSURE PER SQ. FT. AT 70° TEMP.	400 lbs	520 lbs	630 lbs	750 lbs	860 lbs	1,090 lbs	1,170 lbs

* BASED ON THE USE OF MECHANICAL VIBRATION INSIDE THE FORMS

These tables are based on the use of mechanical vibration inside the forms

* LUMBER AND FORM TIE DATA				SAFE SPACING OF STUDS, WALES, AND FORM TIES														
LUMBER SIZES	FORM TIES			POURING TEMPERATURES	50° FAHRENHEIT							70° FAHRENHEIT						
	TYPE	SAFE LOAD	ULTIMATE CAPACITY	RATE OF POUR — FT. OF HEIGHT PER HOUR	2 Ft.	3 Ft.	4 Ft.	5 Ft.	6 Ft.	8 Ft.	10 Ft.	2 Ft.	3 Ft.	4 Ft.	5 Ft.	6 Ft.	8 Ft.	10 Ft.
				CONCRETE PRESSURE PER SQ. FT. OF FORMS	520 lbs	690 lbs	860 lbs	1030 lbs	1210 lbs	1470 lbs	1580 lbs	400 lbs	520 lbs	630 lbs	750 lbs	860 lbs	1090 lbs	1170 lbs
1" (13/16") SHEATHING or 5/8" PLYWOOD	3M Snap Ties; A. C. Ties; No. 2 Rod Clamps with 3/8" Plain Rods	3,000 lbs	4,500 lbs	Stud Spacing for Safe Value of Sheathing	20"	18"	16"	15"	14"	13"	12"	23"	20"	18"	17"	16"	14"	14"
2 x 4 STUDS				Wale Spacing for Safe Value of Studs	30"	27"	26"	24"	23"	22"	22"	31"	30"	28"	27"	26"	24"	23"
2—2 x 4 WALES				Tie Spacing for Safe Value of Ties and/or Wales	27"	23"	19"	17"	15"	13"	12"	32"	27"	24"	21"	19"	16"	16"
1" (13/16") SHEATHING or 3/4" PLYWOOD	5M* Snap Ties; Superties*; Till Locks with 3/8" cold rolled rods; No. 3 Rod Clamps with 1/2" Plain Rods	5,000 lbs	7,500 lbs	Stud Spacing for Safe Value of Sheathing	20"	18"	16"	15"	14"	13"	12"	23"	20"	18"	17"	16"	14"	14"
2 x 4 STUDS				Wale Spacing for Safe Value of Studs	30"	27"	26"	24"	23"	22"	22"	31"	30"	28"	27"	26"	24"	23"
2—2 x 4 WALES				Tie Spacing for Safe Value of Ties and/or Wales	30"	28"	26"	25"	23"	22"	20"	32"	30"	29"	27"	26"	25"	24"
1" (13/16") SHEATHING or 3/4" PLYWOOD	5M* Snap Ties; Till Locks with 3/8" cold rolled rods; No. 3 Rod Clamps with 1/2" Plain Rods	5,000 lbs	7,500 lbs	Stud Spacing for Safe Value of Sheathing	20"	18"	16"	15"	14"	13"	12"	23"	20"	18"	17"	16"	14"	14"
2 x 4 STUDS				Wale Spacing for Safe Value of Studs	30"	27"	26"	24"	23"	22"	22"	31"	30"	28"	27"	26"	24"	23"
2—2 x 6 WALES				Tie Spacing for Safe Value of Ties and/or Wales	46"	38"	32"	29"	25"	22"	20"	56"	46"	40"	35"	32"	27"	26"
1" (13/16") SHEATHING or 3/4" PLYWOOD	1/2" Coil Ties	6,000 lbs	9,000 lbs	Stud Spacing for Safe Value of Sheathing	20"	18"	16"	15"	14"	13"	12"	23"	20"	18"	17"	16"	14"	14"
2 x 4 STUDS				Wale Spacing for Safe Value of Studs	30"	27"	26"	24"	23"	22"	22"	31"	30"	28"	27"	26"	24"	23"
2—2 x 6 WALES				Tie Spacing for Safe Value of Ties and/or Wales	51"	46"	38"	34"	31"	26"	25"	56"	50"	48"	43"	38"	33"	32"
1" (13/16") SHEATHING or 3/4" PLYWOOD	1/2" Coil Ties	6,000 lbs	9,000 lbs	Stud Spacing for Safe Value of Sheathing	20"	18"	16"	15"	14"	13"	12"	23"	20"	18"	17"	16"	14"	14"
2 x 6 STUDS				Wale Spacing for Safe Value of Studs	46"	42"	40"	38"	36"	34"	34"	49"	46"	44"	42"	40"	38"	36"
2—2 x 6 WALES				Tie Spacing for Safe Value of Ties and/or Wales	36"	30"	25"	22"	19"	17"	16"	44"	36"	31"	27"	25"	21"	20"
1" (13/16") SHEATHING or 3/4" PLYWOOD	1/2" and 3/4" Coil Ties; Till Locks with 1/2" cold rolled tie rods	9,000 lbs	13,500 lbs	Stud Spacing for Safe Value of Sheathing	20"	18"	16"	15"	14"	13"	12"	23"	20"	18"	17"	16"	14"	14"
2 x 6 STUDS				Wale Spacing for Safe Value of Studs	46"	42"	40"	38"	36"	34"	34"	49"	46"	44"	42"	40"	38"	36"
2—2 x 6 WALES				Tie Spacing for Safe Value of Ties and/or Wales	42"	38"	35"	33"	30"	26"	24"	47"	42"	39"	36"	35"	31"	30"
1" (13/16") SHEATHING or 3/4" PLYWOOD	1/2" and 3/4" Coil Ties; Till Locks with 1/2" cold rolled tie rods	9,000 lbs	13,500 lbs	Stud Spacing for Safe Value of Sheathing	20"	18"	16"	15"	14"	13"	12"	23"	20"	18"	17"	16"	14"	14"
2 x 6 STUDS				Wale Spacing for Safe Value of Studs	46"	42"	40"	38"	36"	34"	34"	49"	46"	44"	42"	40"	38"	36"
2—3 x 6 WALES				Tie Spacing for Safe Value of Ties and/or Wales	52"	45"	38"	33"	30"	26"	24"	57"	52"	46"	41"	37"	31"	30"
2" (1 5/8") SHEATHING	1/2" and 3/4" Coil Ties; Till Locks with 1/2" cold rolled tie rods	9,000 lbs	13,500 lbs	Stud Spacing for Safe Value of Sheathing	40"	37"	34"	32"	30"	28"	27"	44"	40"	38"	35"	34"	31"	31"
3 x 6 STUDS				Wale Spacing for Safe Value of Studs	42"	38"	35"	33"	32"	30"	29"	45"	42"	39"	37"	34"	33"	32"
2—3 x 6 WALES				Tie Spacing for Safe Value of Ties and/or Wales	41"	37"	35"	33"	31"	29"	29"	45"	39"	38"	37"	36"	32"	31"
1" (13/16") SHEATHING or 3/4" PLYWOOD	3/4" Coil Ties	12,000 lbs	18,000 lbs	Stud Spacing for Safe Value of Sheathing	20"	18"	16"	15"	14"	13"	12"	23"	20"	18"	17"	16"	14"	14"
2 x 6 STUDS				Wale Spacing for Safe Value of Studs	46"	42"	40"	38"	36"	34"	34"	49"	46"	44"	42"	40"	38"	36"
2—2 x 6 WALES				Tie Spacing for Safe Value of Ties and/or Wales	42"	38"	35"	33"	31"	29"	28"	47"	42"	39"	37"	35"	31"	31"
2" (1 5/8") SHEATHING	3/4" Coil Ties	12,000 lbs	18,000 lbs	Stud Spacing for Safe Value of Sheathing	40"	37"	34"	32"	30"	28"	27"	44"	40"	38"	35"	34"	31"	31"
3 x 6 STUDS				Wale Spacing for Safe Value of Studs	42"	38"	35"	33"	32"	30"	29"	45"	42"	39"	37"	34"	33"	32"
2—3 x 6 WALES				Tie Spacing for Safe Value of Ties and/or Wales	41"	37"	35"	33"	31"	29"	29"	45"	39"	38"	37"	36"	32"	31"

*Ultimate Capacity 7,000 lbs.

Courtesy of Superior Concrete Accessories, Inc.

Figure 3-5

Inspector's Check List - Forms Prior to Placing Concrete:

1. Check location, dimensions and alignments of forms, also adequacy of foundation to prevent settlement of forms.

2. Check for sturdiness to make sure the forms are properly braced and have adequate structural strength.

3. Be sure forms are smooth, clean, on the inside, mortar tight, and free from knot holes and blemishes which may be detrimental to the resulting concrete.

4. Check metal form ties and spacers to see that they are properly anchored and may be broken off or withdrawn to leave no metal near exposed concrete surfaces.

5. Be sure all required chamfer strips and grade strips are properly installed.

6. See that metal forms are clean but not abraded to a bright surface.

7. See that forms are wetted or oiled with a non-staining form oil. Make sure there is no oil on re-bars or concrete joint and no surplus on forms.

8. Determine that all foreign material such as chips, blocks, sawdust, dried mortar, and dirt are removed, preferably by air and water.

9. For deep, narrow forms inspection openings should be formed and doors to close these openings built before concreting operations are started. Provisions should also be made for using "elephant trunks" or tremies when required to limit the drop when placing the concrete.

10. Make sure reinforcing steel is free of loose rust or mortar coatings from previous lifts.

Embedded Items.
Items such as anchor bolts, inserts, pipe sleeves, pipes, conduits, wiring, manhole-cover frames, instruments, and other embedded fixtures or mechanical equipment should be firmly fixed in position before concrete is placed unless otherwise specified. Verify from the drawings and specifications that embedded items are correctly located. Wooden inserts that are to be removed, such as keys, joint fillers, and similar items should be well soaked in water in advance of concreting. All embedded items should be free from rust, oil, grease, paint, or other coatings, unless otherwise specified, and protected from damage subsequent to and during the concrete placing operation. Determine that bolt threads or polished surfaces are covered, light metal sleeves or boxes braced internally and open pipe or conduits capped or plugged.

Openings.--It is important that ready access be provided for proper placement, working and vibration of the concrete, and for inspection of the operations. When required, such doors or ports through the forms should be of adequate size and spacing to permit efficient operation and comply with the specifications for conveying and placing the concrete.

Joints and water-stops.--Concrete changes dimensions when under load and when undergoing temperature changes. Plain and reinforced concrete structures should be provided with joints at proper intervals to accommodate the volumetric movements; otherwise, undesirable random cracking may occur. The type and spacing of joints for expansion and contraction vary considerably and depend upon the type of members and the service condition. The location of all expansion joints will be shown on the contract drawings and should not be confused with construction joints. Expansion joints and dowel assemblies should be carefully aligned, and the expansion joint material securely held in place so it will not shift or fall out of position during the placing of concrete.

Water-stops are installed in contracting or expansion joints to provide a joint that will be impervious under pressure. Particular care should be exercised in anchoring the stops in place and in the placing of concrete to obtain thorough filling on either side of the material. In molding concrete around water stops in circular conduits, the points most difficult to properly place concrete are at the top and bottom of the conduit.

Inspector's Check List - Joints and Water-Stops.

1. Determine that all joints (expansion, contraction, construction) are located as shown on the contract drawings.

2. Make sure construction joints have been prepared as required (check specifications for wet sand-blasting, air water cutting, brushing, wetting, etc.).

3. See that contraction joints have been coated with approved material to break bond.

4. See that joint filler has been installed and securely fastened in expansion joints.

5. Determine that expansion joints are free from irregularities or debris which would interfere with free movement.

6. Check all dowel assemblies in expansion joints - dowel sleeves are of correct size and properly positioned - or coatings or wrappings are in place (no fixed metal continuous through the joint).

7. See that water-stops are firmly secured in correct location, undamaged and properly spliced or welded in accordance with manufacturer's instructions (test welds by pulling and twisting).

8. See that mortar has been removed from the exposed edges of expansion joint material after concrete is placed.

Final Inspection Before Concreting.

General.--The final inspection is made immediately before concrete is placed and involves a thorough examination of all preparations. No concrete should be placed until the final inspection has been made and approval given of the items listed herein. It should include a detailed inspection of the foundation clean-up, construction joint clean-up, drain tile and water stops, reinforcement and other metal work and equipment to be embedded, and the forms.

All these features should be carefully examined to make sure they are in accordance with the line, grades, sections and other dimensions shown in the drawings and specifications and conform with any special instructions that have been issued. The inspector should check all surfaces for cleanness and make sure the forms are free from all debris and water immediately prior to placing concrete. He should also see that reinforcement is free of oil, objectionable rust and scale, and mortar from previous pours.

Working conditions.--Immediately prior to the actual placing of concrete, the inspector should determine that all elements and facilities for the operation are in readiness and in proper condition to give the required performance. If it is not clearly evident that the preparatory work is adequate to insure placement of each batch within the specified time after mixing, and at such a rate as to prevent the formation of cold joints, placement should not be allowed to start.

Inspector's Check List - Working Conditions:

1. See that there is an adequate supply of suitable materials on hand for the contemplated work, and that the contractor has made the necessary preparations to conduct the work in a satisfactory manner.

2. Ascertain the sufficiency of personnel, and suitable condition of equipment for mixing, transporting, placing, finishing, and curing, for the entire pour. Check methods and equipment to be used in consolidating or vibrating the concrete. An extra standby vibrator should be available on the job.

3. See that facilities for rain or cold weather protection are at hand.

4. If concrete is to be placed after dark, make sure the lighting arrangements are adequate.

Inspection of Concreting.

Batching of materials.--It is a generally accepted practice to determine mix proportions, and to batch materials by dry weight rather than on the basis of volume. However, the use of sacked cement and measurement of water by volumetric means is not inconsistent since their unit volumes are universally known and are commonly referred to interchangeably.

It is important to check all storage, handling and batching equipment for satisfactory mechanical condition and operating procedures. The accuracy of scales and batching devices should be tested by the methods and at the frequencies specified in the contract. Water and admixture measuring devices should be tested as specified to determine that the equipment operates within the prescribed range of accuracy.

The job mix should be clearly posted at the batching plant to insure against the possibility of using the wrong mix when combining the bulk materials.

The inspector should insist that a batch slip accompany each delivery of concrete, and that each receipt is properly made out and signed as outlined in the specifications.

When the contractor is responsible for the mix and the quality of concrete, there is not always provision made for a plant inspector. The need for and the frequency of these inspections should be considered by the State Technical Staff and scheduled as required for each project.

It should not be overlooked that to get a uniform manufactured product at the job site, the material and batching operations have to be efficiently controlled.

Mixing.--It is essential in mixing concrete that all of the materials be uniformly distributed and the aggregates be well coated with the cement paste. To accomplish these results the mixer must be in good condition, the batch must not exceed the rated capacity of the mixer, and the mixing time and speed must be properly controlled. Mixing blades should not be used that show wear in excess of that permitted by the contract, nor should the blades and interior of the drums be allowed to accumulate a layer of hardened concrete.

Unless limited by the provisions of the contract, mixing water should be fed into the mixer over the full period of charging the dry material, beginning just before and ending just after the dry materials are placed in the mixer. Loss of materials while charging should not be allowed. Cement balls in the mix may be caused by (1) introducing the cement into the mixer ahead of the coarse aggregate, (2) worn mixer blades, (3) hot cement or aggregates, and (4) delaying the initial mixing. Mixing water having temperatures in excess of 150° F. should not be used.

Truck mixers.--Careful inspection is required to obtain uniformity in the low slump ranges from transit mixers. The following procedures and precautions are offered to aid in getting satisfactory concrete from this type of equipment.

1. The mixer should be equipped with an accurate water meter.

2. The mixer should be equipped with a revolution counter to indicate total mixing revolutions. Overmixing can reduce slump especially in hot weather.

3. Concrete ingredients including cement and water should be fed into the mixer in a uniform blend while the mixer drum is turning.

4. The amount of water added at the time of batching should be limited so as to prevent exceeding the specified slump.

Consistency.--The term "concrete consistency" is used to denote the fluidity of concrete as measured by the slump test. The aim in controlling the slump is to control directly the consistency and workability necessary for proper placement, and indirectly the water-cement ratio. When the gradation or moisture content of the aggregates vary, it may be necessary to require adjustments in the batch quantities of the water and aggregates to maintain the slump within the specified range. The need for stable moisture conditions in the aggregates cannot be over-emphasized: To illustrate - a mix which will produce approximately 3000 pounds of concrete may have slump variations in excess of 1 inch, as a result of only 1 percent (by weight) change in surface moisture of the sand.

It is important that the inspector observe the consistency of concrete at the mixer, in conveying devices, and especially at the forms to determine whether the least practicable slump is being used. This can best be judged by its workability in the forms and the way it finishes. The inspector should occasionally spade or work the concrete himself to judge its suitability.

<u>Inspector's Check List - Batching and Mixing</u>:

1. Determine that batching equipment is in good condition, has adequate capacity and that each hopper completely discharges.

2. Check aggregate and cement scales for performance upon repeated loading. Aggregate scales should be checked at increments of 500 pounds, up to a total of 3,000 pound load.

   Cement scales should be checked at increments of 100 pounds to full batch load.

3. See that aggregates are stockpiled on cleared smooth surfaces free from dust, mud or water. Allow adequate time for aggregates to free drain prior to use.

4. Do not permit methods of stockpiling that will cause segregation or overlapping of sizes of aggregates.

5. Check sieve analysis of aggregates, as required, to determine gradation is consistent with the materials used in the mix design.

6. Check accuracy of equipment for measuring air entraining agent.

7. Make sure air entraining admixture is added with the mixing water.

8. Determine that the specified type of cement is used in the concrete.

9. When the engineer is responsible for the mix, determine the amount of free moisture in the aggregates prior to batching.

   Tests should always be made after rains or delivery of new supply of material.

10. See that the concrete mixing drum and discharge chute are free of hardened concrete.

11. Check that wear on mixing blades does not exceed the specified tolerance.

12. Make sure that water tanks, pipes and fittings are in good condition and that valves shut off tightly.

13. Check accuracy of water measuring equipment at variable settings.

14. See that the mixing equipment is not loaded in excess of the manufacturer's rating (rating plate should be displayed on the equipment).

15. Determine that the rate of rotation of the mixer drum, when fully loaded, meets the manufacturer's specification, and that the revolution counter operates properly.

16. Observe each batch for uniformity at the time of placement. Any change from normal consistency or appearance indicates a deviation from the approved mix.

17. Maintain complete record of tests of all rejected concrete, and the reason for rejection of the batch. If rejected concrete is placed, record exact location material was placed in the structure and make at least one set of test cylinders to verify the strength of the rejected material. (The inspector also should, as soon as convenient, notify his superior all the facts relating to the rejected concrete.)

18. See that additional water is not added to retemper concrete.

19. See that properly prepared batch tickets are delivered with each load of transit mix concrete.

20. Determine that certification for quality of all ingredients used in the manufacture of the concrete have been received.

21. See that required tests are performed and that cylinders for strength test are molded, identified, handled and cured as specified.

Delivery and placing.--Even though concrete is carefully designed and properly mixed, its quality may be seriously impaired by use of improper or careless methods in transporting and placing. The contractor has the option, within the limitations of the construction specifications, to select the methods and facilities to be used. He is nevertheless responsible for the suitability of such facilities and methods. Requirements for minimizing segregation should be strictly observed in all handling and placing operations, and any equipment incapable of producing acceptable results should be promptly modified or replaced. It is essential to avoid segregation of the coarse aggregate from the mortar or water from the other ingredients.

When discharge is at an angle from the mixer or conveyor, the larger aggregate is thrown to the far side of the container or form being charged and the mortar is thrown to the near side. For this reason, all hoppers, chutes, buckets, and other forms of conveyor should be provided with vertical drops at the point of discharge.

Concrete can be handled and transported by a number of methods, including chutes, buggies, crane operated buckets, trucks, conveyor belts or by pumping. The method of handling and transporting concrete or the equipment used should not place any restriction on the consistency of the concrete. Consistency should be governed entirely by the specifications and the equipment should be adapted to meet those requirements.

In placing concrete for slab construction, the first batch should be placed at the far end of the work and each batch then dumped against previously placed concrete, not away from it. The concrete should not be dumped in separate piles and then leveled and integrated.

The order of placing concrete is also important. In walls, the first batches, when practical, should be placed at either end of the section, then placing should progress toward the center. This same procedure should be used for each layer. In all cases, the procedure should be such as to prevent water from collecting at the ends and corners and along form faces. Figure 3-6 taken from the Portland Cement Association publication, "Design and Control of Concrete Mixtures", shows correct and incorrect methods of placing concrete.

Continuous inspection must be provided during the placing operation. Inspectors should see that the following conditions and requirements are fully complied with unless exceptions are specifically authorized.

1. Make sure that concrete is conveyed from the mixer or truck mixer to the forms or sub-grades as rapidly as practical, and by methods which will prevent segregation or loss of ingredients. Concrete which is not within the specified slump should be rejected.

2. When chutes are used, see that concrete slides in a uniform mass without segregating. Slopes of chutes should not be greater than 1 horizontal to 2 vertical, unless baffles are provided.

3. Do not allow vertical drops greater than 5 feet without the use of elephant trunk, tremie or other devices to prevent segregation.

4. Allow placement of no more concrete at one time than can be satisfactorily consolidated and properly finished.

5. Insist that concrete be deposited as close as possible to its final position. Prevent excessive rehandling, and lateral flow of concrete by vibrators.

6. Be sure vibrators are operated so as not to distort forms. Check forms continually during placing operations to insure that wedges, ties and bracing have not loosened or failed and that forms have not moved.

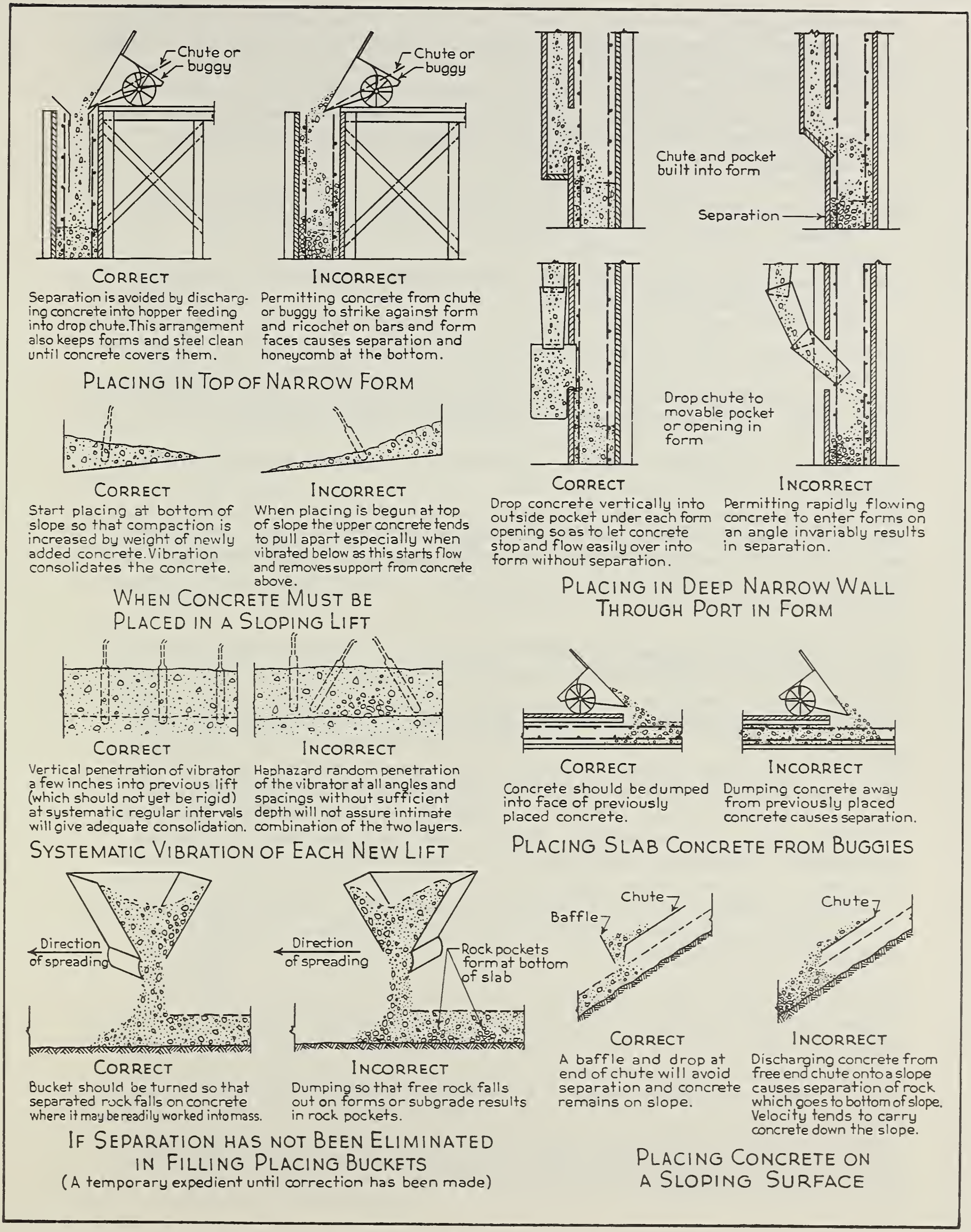
7. Place concrete in uniform horizontal layers (not over 20 inches deep). Placement should be continuous until the monolith is completed. If continuous placing is interrupted long enough for initial hardening to take place, require that a proper construction joint be made.

8. Make sure that the time lapse between batching and final placement in the forms is within the maximum allowed by the specifications.

9. Prevent excessive accumulation of laitance by changing the consistency of the concrete.

10. Allow at least 12 hours before placing a new pour on construction joints. Before placing is resumed, remove excessive water and all laitance from the construction joints.

11. Upon completion of placing concrete to finished grade, encourage the contractor to carry top surfaces sufficiently above grade to insure that good quality concrete remains when the top surfaces are struck off and finished.



Correct and incorrect methods of placing concrete. Adapted from *Recommended Practice for Measuring, Mixing and Placing Concrete* (ACI 614-42) of the American Concrete Institute. (Fig. 3-6 taken from the PCA publication, "Design and Control of Concrete Mixtures," Tenth Edition)

Figure 3-6

12. Consolidate all concrete with the aid of a mechanical vibrator as approved by the engineer. Vibration should not be applied through the forms or used to place the concrete laterally. Vibration should be supplemented by hand spading adjacent to the forms on exposed faces. Prevent either under or over-vibration which may cause honeycombing, segregation, sandstreaking and excessive laitance.

13. Do not permit over-working, or over-finishing of concrete surfaces.

14. Do not allow the addition of water to the surface of fresh concrete to aid finishing.

Consolidation.--The use of mechanical vibrators as an aid to consolidation of concrete has been mentioned in the preceding discussion covering the placing operations. Reference is also made to Figure 3-6, which shows the proper methods of vibrating fresh concrete.

The objective in consolidating concrete, as the word implies, is the elimination, so far as is practical, of voids within the concrete. Well consolidated concrete is free of large bubbles of entrapped air and rock pockets, and is in close contact with the forms, reinforcement, and other embedded items. Accomplishment of this objective is not possible if segregation and decrease in slump occurs during transportation and deposition of the concrete.

Use of vibrating equipment makes it possible to place a mix that would be considered unworkable for compaction by hand. This is particularly beneficial when working in deep, narrow forms or around closely spaced reinforcement because stiff mixes which have less tendency to segregate can be used. Vibration cannot be expected to correct segregation which has taken place due to faulty methods of handling and placing. Vibration should continue only until the concrete is thoroughly consolidated and the voids filled, as evidenced by the leveled appearance of the concrete at the exposed surface and the embedment of surface aggregates. Vibration continued beyond this period is not effective and tends to cause coarse aggregates to settle to the bottom and water or paste to rise to the top. On the other hand, concrete which readily segregates from vibration should have the slump reduced rather than the amount of vibration. Poor results can more often be traced to under-vibration rather than over-vibration. When an air-entrained concrete is used, over-vibration should be avoided as it tends to reduce the air content. Ordinarily vibration should secure the desired results within 5 to 15 seconds at points uniformly spaced not farther apart than the radius over which the vibrator is visibly effective, usually about 18 inches apart. An internal vibrator should be operated from a vertical position and inserted and withdrawn slowly so that the space occupied by the unit will be filled. The depth of operation should be full depth of the layer being placed and into the previous lift of fresh concrete.

Conctruction joints.--Construction joints as distinguished from expansion joints are not provided to permit movement between adjacent sections of a structure but are made necessary by construction requirements. They mark the top or end of a lift or the completion of a day's pour. Since construction joints are points of weakness with regard to water-tightness and resistance to weathering, they should be avoided insofar as possible and should be properly located, and well bonded. The inspector is reminded of the precautionary measures to be taken as mentioned previously under the discussion on forming at construction joints. The clean-up operation to remove laitance, debris, and loose concrete and preparation of the surface preparatory to placing fresh concrete at a construction joint are essential to obtaining good bond. The requirements in the specifications and on the drawings must be complied with as to the inclusion of waterstops or other special provisions for insuring watertightness in the joints.

Finishing.--Concrete finishing includes the required treatment of exposed nonformed surfaces at the conclusion of the placing operation, and the repair of surface defects and filling of the spacer or snaptie holes following the removal of forms from formed elements of the structure.

The following items should be given attention by the inspector in connection with finishing and repairing surface defects:

Nonformed Surfaces.

1. See that concrete is spread evenly ahead of strike-off screed, and struck off to approximate line and grade.

2. Concrete should be worked only enough to produce sufficient mortar on the surface for finishing.

3. See that any excess water is allowed to evaporate before permitting final float finish.

4. Make sure the finish meets the requirements of the contract.

5. Do not allow "dusting" or sprinkling of dry cement or other material on the surface to absorb excess water. Do not permit the addition of water to the surface to aid in finishing.

6. See that joints and edges are traced with an edging tool and excessive mortar removed.

7. If special finish is required, see that qualified cement finishers are available.

8. Check metal trowel finish for uniformity and texture of surface - a magnesium trowel gives superior finish for air entrained concrete.

Formed Surfaces.

1. Inspect concrete surfaces immediately after forms are removed to determine extent and kind of corrective action required. Check that surfaces meet the smoothness and alignment tolerances specified.

2. Make sure all tie rod holes are moist and are packed with an approved patching mortar. Insist that the material has good bond, and is uniformly finished.

3. See that fins and form marks are removed and rubbed smooth, as specified.

4. Make sure all honeycombed or damaged areas are cut out to expose sound concrete and filled as specified with concrete matching that of the structure.

5. See that rough areas and high spots are rubbed or ground to the degree of smoothness or tolerance specified.

<u>Inspection After Concreting</u>.

Form Removal.--Determination of the time of form removal should be based on the effect on the concrete. When forms are stripped there should be no measurable deflection or distortion and no evidence of damage to the concrete, due either to removal of support or to the stripping operation. Time limitations called for in the specifications must be strictly adhered to.

Forms should be removed at the earliest practicable time so that curing may proceed without delay and so that any necessary repairs or surface treatment can be accomplished while the concrete is still green and conditions are most favorable for good bond. The forms should be removed with care so as not to damage the finished concrete.

Curing.--The object of curing is to prevent or replenish the loss of needed moisture during the early rapid stage of hydration. The water content of fresh concrete is considerably more than enough for hydration of the cement. However, an appreciable loss of this water by evaporation or otherwise after initial set has taken place may delay or prevent complete hydration.

The usual procedure for water curing concrete is to keep the exposed surface continually moist by spraying or ponding, or by covering with earth or burlap maintained in a moist condition. The curing methods followed should be effectively maintained for the specified period.

Sealing compounds of approved types may be used as a curing membrane if authorized in the specifications. The application of a sealing compound should be applied as soon as the surface of unformed concrete will permit after placement and immediately after repair of formed surfaces.

The sealing compound, preferably, is applied in one coat by spraying. To insure thorough and complete coverage, approximately one-half of the compound for a given area should be applied by moving the spray back and forth in one direction, and the remainder of the coating applied at right angles to the first direction.

Spraying equipment should be of the pressure-tank type. If compressed air lines are used, they should be trapped to prevent moisture or oil from getting into the compound. It is important that the sealing compound is applied promptly after the forms are removed. Special care should be taken with formed concrete to see that edges, corners, and rough spots are well covered with compound. The compound should not be applied before patching is done. Only those sealing compounds that fully meet the specifications should be accepted for use on the job.

Inspector's Check List - Curing Concrete.

1. Determine that adequate curing and protective arrangements have been made before permitting concrete placing operations to start.

2. Make sure that the concrete is kept moist and warm so that hydration of the cement can take place.

3. See that the curing media is applied to nonformed surfaces as soon as the concrete hardens sufficiently to be undamaged by its application.

4. Make sure that the water used for curing meets the requirements of the specifications.

5. See that the forms and the concrete prior to removal and the concrete after removal of the forms are kept wet as specified.

6. Make sure that certificate for quality of curing compound has been received prior to its use and the rate of application is in accordance with the specifications.

7. Do not permit application of curing compound before the required repairs or patching of the concrete surface has been completed.

8. Make sure that curing compound is not applied to or that it is completely removed from the concrete and reinforcing steel surfaces where bond is required.

9. During cold weather, see that adequate equipment and protection are provided to maintain the concrete at the specified temperature for the curing period.

Protection from damage.--The contractor is required to protect all concrete from injury and damage until final acceptance by the contracting agency. He must take the necessary precautions to keep equipment away from the concrete until such time as the concrete has set

sufficiently and soil has been tamped over and around the structure. Necessary precautions should also be taken for hot or cold weather protection.

Special attention should be given to the following:

1. Avoid overloading, jarring or surface marring of green concrete.

2. Falsework should be left in place until concrete has hardened sufficiently to support its own weight.

3. Do not permit loads on projecting reinforcement.

4. Backfilling should be done with care not to overload or damage the concrete.

5. Do not permit fires on or adjacent to unprotected concrete.

6. See that following steps as required in the specifications are taken in the manufacture and curing of concrete when temperature of the concrete exceeds 90° F.

    (a) Add ice to mixing water or use other procedures to reduce concrete temperature.

    (b) Use water in fine spray to keep concrete surfaces moist after placement and during the finishing operation.

    (c) Keep all surfaces exposed to air wet after placement for the period specified in the contract.

    (d) At expiration of the initial wet curing period, add curing compound or continue water application for duration of curing period.

<u>Testing of Concrete</u>. (See Chapter 4 - Sampling and Testing).
Sampling.--The recommended methods for sampling fresh concrete are set forth in ASTM Designation C 172 and are also covered in Test No. C-1, Chapter 4. The samples should be representative of the concrete being placed.

Number of Test Specimens.--It is not practical to suggest a fast rule that will govern the frequency for making concrete strength tests for all kinds of work. The Government representative and the State Conservation Engineer should consider the type and requirements for the proposed concrete structures planned for each contract, and schedule the minimum number of tests required for each structure and class of concrete.

It should be kept in mind that when strength concrete is specified, the strength tests provide primary evidence of conformance. Therefore, adequate testing is essential and important for both technical and administrative control of the contract.

It has proven desirable to make more frequent tests at the start of the concrete operations to verify the suitability of the mix. Also, it is beneficial to make additional cylinders for the first few pours so that tests may be made at one or two weeks, or some other early date to provide an indication of the potential 28-day strength.

It is suggested that at least one test be made for each 75 cu. yds. of concrete placed in reinforced structural work, including rectangular channel linings and at least one test be made for each 150 cu.yds. of concrete placed in trapezoidal linings, slabs or other work that is non-reinforced or reinforced only for temperature stresses. Also, that a minimum of one test be made for each day's pour.

More frequent tests may be necessary for critical elements of a given structure, or when materials, equipment, weather or other conditions present the need for verifying strength results. Conversely, fewer tests may be required after the job mix is proven and all manufacturing operations are satisfactory and well controlled.

The requirement for a test to be made on each day's pour may not always be necessary for minor work, such as, farm irrigation or drainage structures, channel side drainage structures and other structures of this type, if the mix has proven to meet all the requirements.

The inspector should always recognize the need to make tests whenever the mix delivered to the site gives evidence that some change from the normal has taken place.

Method of molding specimens.--The procedure for molding test cylinders required for making compressive strength tests is described in Test No. C-3, Chapter 4.

Slump and air entrainment.--The procedure for constructing the slump cone and for making the slump test for consistency is described in Fed. Spec. SS-R-406, Test Method 232.0, "Test for Slump of Portland Cement Concrete." The procedure for making the slump test is included in Test No. C-2, Chapter 4.

The slump test should be made at such frequency as required to ascertain that the concrete delivered to the site is within the slump limits prescribed by the specifications. Slump tests should definitely be taken when there is an apparent change in the consistency of the concrete and when a sample is taken for tests to determine strength.

The tests for the amount of entrained air in the mix is outlined in Tests No. C-5, C-6, and C-7, Chapter 4. The pressure test equipment (Washington Type Air Meter) required for test C-5, is not affected by change in atmospheric pressure and is considered to have preference over other equipment for use in contract control tests.

Curing specimens. --The procedures for curing test cylinders are described in ASTM Designation C-31. Standard cured specimens are tested to indicate the potential strength of the concrete and require

that the specimens be moist cured at controlled temperatures for the prescribed period. Test specimens that are to be tested to check the adequacy of the design mix or as the basis for acceptance of the concrete structure should remain in the molds for the first 24 hours. Immediately after molding they should be stored under conditions that maintain the temperature immediately adjacent to the specimen in the range of 60 to 80 degrees F., and so as to prevent loss of moisture from the specimens.

Under hot weather conditions the use of wet burlap or sand may be required. For low temperatures, heating devices such as stoves, electric light bulbs or other means may be used, providing the required temperature and moisture loss conditions are met.

At the end of the 24-hour period, the test specimen should either be shipped to the laboratory or removed from the molds and stored in a controlled lime solution which is maintained at a temperature of 73.4 $\pm$ 3.0 degrees F., until the time of test.

Job curing is intended to provide a basis for determining when a structure may be placed in service. Test cylinders cured in this manner are subjected to the same field conditions and protection from the elements as the structure which they represent. At the end of 24 hours, the test specimens should be removed from the molds and stored in the structure as near to the portion of the structure being sampled as possible. They should receive the same protection from the elements on all surfaces as given to the portions of the structure being tested. If the structure is treated with curing compound, the test cylinders should be sprayed at the same time the structure is treated.

Handling and shipping specimens.--Specimens should be protected at early ages from jarring and vibration, and at all ages from damage by rough handling. They should be maintained upright until they have hardened. Careful treatment of test specimens is absolutely necessary; otherwise, test results are misleading. Samples that are to be laboratory cured should be handled and protected as required in ASTM Designation C-31, Subsection (7).

Specimens to be cured by a testing laboratory should be shipped to the laboratory at the age of one day. All cylinders should be packed in wet cushioning material, such as sawdust or burlap for shipment.

Each shipment of specimens should be accompanied by complete identification and pertinent data regarding the conditions under which the specimens were made and the test requirement. In general, the information should include the date, location in the structure represented by the sample, mix, slump, amount of air entrainment or other admixtures, concrete and air temperatures, curing method, kind of test, and age at which the test is to be made. Form SCS-59, "Data on Concrete Test Specimens", has been prepared for recording this information.

Age of test.--Tests made prior to 28 days are desirable at the beginning of a job to aid in determining the adequacy of the mix. The specified age of a test cylinder to determine strength of concrete is 28 days. Under given conditions the expected minimum strength at 28 days may be approximated from tests made at some earlier age, say 7 or 14 days. For high early strength cements, a test at 1 or 3 days is indicative of the ultimate strength that may be attained.

Early age test results are not conclusive and should be evaluated only as an indicator of potential strength. If the early tests are assumed to be low or marginal, the contractor may choose to supply a higher strength mix or discontinue concrete operations until such time as the 28-day tests prove the adequacy of the mix.

Records and Reports.
Mix computations.--The records showing computations for trial mixes, adjustments, and selection of the job mix or documentation of the contractor's proposed mix and approval thereof should be made a part of the contract files. Accepted methods for determining mix proportions are discussed in detail in the concrete manuals listed as references in this guide.

Batching and mixing records.--The batching and mixing records are kept by the inspector. A summary of these records together with the volume of each class of concrete placed should be entered daily in the Job Diary.

For some projects it may be determined to be necessary to maintain an inspector at the batching plant during the concrete placing operation. For this arrangement, the plant inspector would rightfully be responsible for maintaining the batching records. Form SCS-544, "Daily Concrete Batching Record", (see Figure 5-2) may be used by the plant inspector to record the detail daily batching operations.

Record of placing and curing.--A record of the placement of concrete detailing the amount placed in the individual parts of the structure cast during the day's operations should be made. A record of the beginning of curing operations, removal of forms, repair of defective surfaces, and ending of curing, all should be made in the Job Diary.

Record of Strength Test Specimens.
A cross reference to each SCS-59 "Report on Concrete Test Specimens", should be recorded in the Job Diary. This reference should include the SCS-59 report number, the numbers assigned to the test specimens molded for the day, and a record of the test specimens shipped to the laboratory. The entry should also indicate the location and amount of concrete represented by each strength test.

Strength Tests of In-Place Concrete. (Use of the impact type concrete testing hammer)
When cylinder tests do not meet the requirements specified for strength concrete, it becomes a technical and administrative problem to determing acceptance or rejection of the structure or the portion of the

structure represented by the low strength tests. If recommended by the contracting officer, and concurred in by all interested parties to the contract, tests may be made on the in-place concrete in the structure.

Compressive strength tests made on core samples cut from the structure, using recognized standard test methods, may be used to secure additional data on the competence of the concrete.

The delineation of the area of questionable strength concrete in the structure may be evaluated by the use of the impact type concrete testing hammer. This light weight instrument, often referred to as the "Swiss Hammer" is a hand operated unit that works on the impact principle. Test results are based on an empirical relationship between strength of concrete and the rebound of a steel plunger. The plunger is pressed against the concrete surface gradually increasing the pressure until the hammer impacts. The rebound number is read on an indicator dial. This reading is referred to a calibration curve which has been developed to show the compressive strength of the concrete. Accuracy of the test results can be improved by calibrating the hammer for the particular concrete mix. Calibration is obtained by correlating hammer readings made on the test cylinders for the mix with the actual breaking strengths recorded for the cylinder.

The cylinders should be placed against a solid surface to prevent movement when tested with the hammer.

In order to get uniform results, it is necessary for all tests to be made on a smooth flat surface of the concrete. A carborundum stone is furnished for this purpose.

The use of the impact hammer is not to be used to determine concrete strength for acceptance. Also, it is not recommended that the hammer be used to determine the earliest time that forms may be stripped.

This unit, when operated in accordance with the manufacturer's instructions, is recognized to be accurate within the range of 10 to 15 percent.

Steel Reinforcement for Concrete

General.
Plain concrete is strong in compression and shear, but lacking in strength to resist tension. The ratio is about 10 to 1, therefore, steel reinforcement must be used wherever tension forces of any magnitude occurs. The drawings will show sizes and locations for all required reinforcement. The inspector must understand the drawings and the intent of the design to determine that the steel setters place the reinforcement as required. In addition to the contract drawings, it is not uncommon for the steel fabricator to prepare placing plans which list each structural member and outline in detail the bars that are required and the location where each bar is to be placed. The contractor should furnish copies of any additional lists or placing diagrams which he may have for the use of the inspector in checking the reinforcement in place.

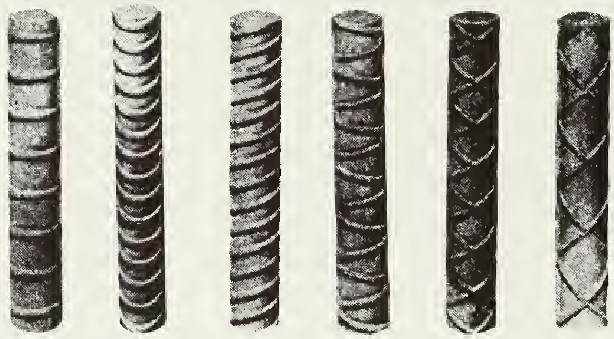
Materials.
Properly documented certificates should be furnished by the contractor showing that the steel reinforcement meets the requirements of the specifications. Samples should be taken and tests run if there is any question of quality.

Deformations.--The bond (resistance to slippage) depends upon the height of the deformation on the bar, the angle they make with the axis, and the spacing. Deformations must conform to the requirements set forth in the specifications.

Figure 3-7 shows the more common types of standard deformations, and the American standard bar marks used for the three kinds of rebar steel.

Bar sizes.--Under approval of the U. S. Department of Commerce, Simplified Practice Recommendation 26, ten standard sizes of reinforcing bars, designated as #2 to #11, inclusive, have been accepted by industry and are available at most plants. Under present standards, the #2 is a plain round bar, the #3 to #11, inclusive, are deformed bars. Figure 3-7 shows the number, sizes and weights of the standard and special sizes available. The over-all maximum diameter, including the deformations, may vary slightly since bar diameters are nominal. For the preparation of holes, or for checking sleeve sizes, the over-all diameter may be determined by adding 1/16 inch to the #3, #4, and #5 bars; 1/8 inch to #6, #7, #8, and #9 bars, and 3/16 inch to #10 and #11 bars.

Lengths and Bending.
Fabricated reinforcement may be furnished to the jobs as cut-to-length which are straight bars cut to length and bundled by size and length, or cut-and-bent bars which have been completely fabricated to include cutting and bending. In either case, the supplier shop-details all bars, lists them by number, cuts and bends to certain tolerances and bundles and tags the order. Purchase by the contractor from the fabricator is becoming more prevalent. For the larger jobs, the contractor may choose to subcontract the steel to the fabricator which will



VARIOUS TYPES OF DEFORMED BARS

TABLE I—STANDARD REINFORCING BARS

BAR SIZES		WEIGHT	NOMINAL DIM.—ROUND SEC.		
OLD (Inches)	NEW (Numerals)	POUNDS PER FOOT	DIAMETER INCHES	CROSS SEC. AREA, SQ. IN.	PERIMETER INCHES
¼	#2	.167	.250	.05	.786
⅜	#3	.376	.375	.11	1.178
½	#4	.668	.500	.20	1.571
⅝	#5	1.043	.625	.31	1.963
¾	#6	1.502	.750	.44	2.356
⅞	#7	2.044	.875	.60	2.749
1	#8	2.670	1.000	.79	3.142
1	#9	3.400	1.128	1.00	3.544
1⅛	#10	4.303	1.270	1.27	3.990
1¼	#11	5.313	1.410	1.56	4.430

The new bar numbers are based on the number of ⅛ inches included in the nominal diameter of the bar.

Bar #2 in plain rounds only. Bars #9, #10 and #11 are round bars and equivalent in weight and nominal cross sectional area to old type 1", 1⅛" and 1¼" square bars.

These weights were adopted as standards by the Institute in 1934 and approved through U.S. Department of Commerce Simplified Practice Recommendation 26.

SPECIAL DEFORMED ROUND STEEL BARS
ASTM Designation (A 408-57T)

BAR SIZES		WEIGHT	NOMINAL DIM.—ROUND SEC.		
OLD (Inches)	NEW (Numerals)	POUNDS PER FOOT	DIAMETER INCHES	CROSS SEC. AREA, SQ. IN.	PERIMETER INCHES
1½	14S	7.65	1.693	2.25	5.32
2	18S	13.60	2.257	4.00	7.09

These large bars are outside the scope of ASTM A15 for Billet Steel Bars and ASTM A305 for Deformations.

Sizes #14S and #18S reinforcing bars are not carried in regular stock. These sizes available only by special arrangement with your supplier.

CONCRETE REINFORCING STEEL INSTITUTE

Figure 3-7

include all reinforcing materials, fabrication, transportation, labor, and incidentals complete in place. Only for very small quantities and relatively small bars will the contractor purchase the steel and do his own fabrication on the job.

Various names have been assigned to reinforcement when cut and bent to a certain shape. Each shape has a definite functional use. Some of the standard types are truss, stirrups, ties, spirals, radial bends, continuous slab, corner bars, off-set column bars, hook and standard patterns for fabrication of typical bends. Various technical and research groups, such as Concrete Reinforcing Steel Institute, American Concrete Institute, Portland Cement Association, working with the steel industry and building code formulation groups have standardized many of the fabrication procedures and tolerances for the cutting and bending of steel reinforcement. It is not necessary to give space to complete documentation on all the standard types of bars and bends; rather it is suggested that the inspector review pages 49 to 50, inclusive, in the handbook C.R.S.I. "Recommended Practice for Placing Reinforcing Bars." This publication gives excellent coverage for the more common bending procedures now in general use throughout the industry.

<u>Limits of Tolerance in Fabrication</u>.
The following deviations in bar length from the true dimensions shown on the drawings are within the tolerance limits used by many fabricators, and will be accepted on Service projects unless specified otherwise. (The following data reproduced through the courtesy of the "Concrete Reinforcing Steel Institute.")

<u>Length-straight bars</u> -- ± 1 inch

<u>Bars with hooks</u>

Over-all dimensions - #7 and smaller ± 1/2 inch

#8 and larger ± 1 inch

<u>Truss bars</u>

Over-all dimension-length #7 and smaller ± 1/2 inch

#8 and larger ± 1 inch

height plus 0, minus 1/2 inch

<u>Spirals, circles or column ties</u>

Over-all dimension ± 1/2 inch

<u>Stirrups</u>

Over-all dimension ± 1/2 inch

The manufacturer of reinforcing bars is allowed a variation of ± 3 1/2 percent in total weight for one lot of deformed bars and a maximum of 6 percent under weight for any individual bar.

Indentification.

Reinforcing which has been fabricated for a project should be bundled and tagged for identification. Various methods of tagging are used. For the most part, the steel will be bundled to contain bars of one size, length and mark. Each bundle should have a tag showing name of purchaser or order number, number of pieces, length and an identification showing the location in the structure. The marking system used to show location of placement will be by predetermined symbols or marks. Various methods and systems prevail. It is the responsibility of the inspector to determine, at the time of delivery, the system that is used by the fabricator so that he can determine that the materials are satisfactory for the job. The contractor should supply the inspector with copies of the delivery invoice and also copies of the fabricator's bar bending and placing diagrams that he may have prepared for the work.

Welded Wire Fabric.

Welded wire fabric, often referred to as wire mesh, may be furnished to the project in rolls for the lighter gage and in large sheets for the heavier sizes of reinforcement.

Wire fabric is manufactured in square and rectangular pattern, and may be one way reinforcement with heavy wires at close spacing in the lengthwise direction, or two way with equal wires at equal spacing.

The same precautions for storage on the job and keeping the fabric free from loose rust and other coatings prevail as outlined for bar reinforcement.

Careful inspection should be made of the in-place fabric to make sure the material is of the specified size and spacing and that the fabric is spliced and supported in place as required in the specifications for the work.

The data included in Figures 3-8 and 3-9 represents the styles, and the wire sizes and spacing that are commonly produced by the manufacturers.

Handling and Storage.

In nearly every instance steel reinforcement is delivered to the project by truck. It is important that the material is unloaded in a manner that will not bend or otherwise damage the material at the unloading site. Complete delivery for a large project which includes various sizes and shapes should be unloaded in a yard or area satisfactorily prepared with wood or other approved supports so that the bundles may be separated by size, shape, and structure for proper inspection. All steel should be stored off the ground until delivered to the structure for placement.

TABLE VIII—COMMON STYLES OF RECTANGULAR WELDED WIRE FABRIC—ONE-WAY TYPES

Style designation	Spacing of wires, in.		Size of wires AS&W gauge		Sectional area sq in. per ft		Weight lb per 100 sq ft
	Longit.	Trans.	Longit.	Trans.	Longit.	Trans.	
24-1414 *	2	4	14	14	.030	.015	16
212-04	2	12	0	4	.443	.040	169
212-15	2	12	1	5	.377	.034	144
212-26	2	12	2	6	.325	.029	124
212-37	2	12	3	7	.280	.025	107
212-48	2	12	4	8	.239	.021	91
212-59	2	12	5	9	.202	.017	77
212-610	2	12	6	10	.174	.014	66
212-711	2	12	7	11	.148	.011	56
312-04	3	12	0	4	.295	.040	119
312-15	3	12	1	5	.252	.034	102
312-26	3	12	2	6	.216	.029	87
312-37	3	12	3	7	.187	.025	75
312-48	3	12	4	8	.159	.021	64
312-59	3	12	5	9	.135	.017	54
312-610	3	12	6	10	.116	.014	46
312-711	3	12	7	11	.098	.011	39
312-812	3	12	8	12	.082	.009	32
412-26	4	12	2	6	.162	.029	69
412-37	4	12	3	7	.140	.025	59
412-48	4	12	4	8	.120	.021	51
412-59	4	12	5	9	.101	.017	43
412-610	4	12	6	10	.087	.014	36
412-711	4	12	7	11	.074	.011	31
412-810	4	12	8	10	.062	.014	27
412-812	4	12	8	12	.062	.009	25
412-912	4	12	9	12	.052	.009	22
412-1012	4	12	10	12	.043	.009	19
412-1112 *	4	12	11	12	.034	.009	16
412-1212 *	4	12	12	12	.026	.009	13

*See footnote

TABLE VIII—COMMON STYLES OF RECTANGULAR WELDED WIRE FABRIC—ONE-WAY TYPES—(Cont.)

Style designation	Spacing of wires, in.		Size of wires AS&W gauge		Sectional area sq in. per ft		Weight lb per 100 sq ft
	Longit.	Trans.	Longit.	Trans.	Longit.	Trans.	
48-711	4	8	7	11	.074	.017	33
48-812	4	8	8	12	.062	.013	27
48-912	4	8	9	12	.052	.013	23
48-1012	4	8	10	12	.043	.013	20
48-1112 *	4	8	11	12	.034	.013	17
48-1212 *	4	8	12	12	.026	.013	14
48-1214 *	4	8	12	14	.026	.008	12
612-3/04	6	12	000	4	.206	.040	91
612-2/04	6	12	00	4	.172	.040	78
612-00	6	12	0	0	.148	.074	81
612-03	6	12	0	3	.148	.047	72
612-11	6	12	1	1	.126	.063	69
612-14	6	12	1	4	.126	.040	61
612-22	6	12	2	2	.108	.054	59
612-25	6	12	2	5	.108	.034	52
612-33	6	12	3	3	.093	.047	51
612-44	6	12	4	4	.080	.040	44
612-66	6	12	6	6	.058	.029	32
612-77	6	12	7	7	.049	.025	27

Fabric with longitudinal wires up to and including 7/0 can be furnished.

*The styles of fabric listed above are standard and are obtainable from stock. If additional transverse steel area is required the gauge and spacing of the transverse wires may be changed from that indicated above—usually for orders of 5 tons or more.

Figure 3-8

TABLE IX—COMMON STYLES OF SQUARE WELDED WIRE FABRIC—TWO-WAY TYPES

Style designation	Spacing of wires, in.		Size of wires AS&W gauge		Sectional area sq in. per ft		Weight lb per 100 sq ft
	Longit.	Trans.	Longit.	Trans.	Longit.	Trans.	
2 x 2—10/10	2	2	10	10	.086	.086	60
2 x 2—12/12 *	2	2	12	12	.052	.052	37
2 x 2—14/14 *	2	2	14	14	.030	.030	21
2 x 2—16/16 *	2	2	16	16	.018	.018	13
3 x 3—8/8	3	3	8	8	.082	.082	58
3 x 3—10/10	3	3	10	10	.057	.057	41
3 x 3—12/12 *	3	3	12	12	.035	.035	25
3 x 3—14/14 *	3	3	14	14	.020	.020	14
4 x 4—4/4	4	4	4	4	.120	.120	85
4 x 4—6/6	4	4	6	6	.087	.087	62
4 x 4—8/8	4	4	8	8	.062	.062	44
4 x 4—10/10	4	4	10	10	.043	.043	31
4 x 4—12/12 *	4	4	12	12	.026	.026	19
4 x 4—13/13 *	4	4	13	13	.020	.020	14
4 x 4—14/14 *	4	4	14	14	.015	.015	11
6 x 6—0/0	6	6	0	0	.148	.148	107
6 x 6—1/1	6	6	1	1	.126	.126	91
6 x 6—2/2	6	6	2	2	.108	.108	78
6 x 6—3/3	6	6	3	3	.093	.093	68
6 x 6—4/4	6	6	4	4	.080	.080	58
6 x 6—4/6	6	6	4	6	.080	.058	50
6 x 6—5/5	6	6	5	5	.067	.067	49
6 x 6—6/6	6	6	6	6	.058	.058	42
6 x 6—7/7	6	6	7	7	.049	.049	36
6 x 6—8/8	6	6	8	8	.041	.041	30
6 x 6—9/9	6	6	9	9	.035	.035	25
6 x 6—10/10	6	6	10	10	.029	.029	21

* Usually furnished only in galvanized wire.

Two-way fabric usually consists of equal-sized wires, equally spaced in both directions, as shown in the above table.

CONCRETE REINFORCING STEEL INSTITUTE

Figure 3-9

Proper Location of Steel in Structure Members.
Those responsible for inspection must determine in advance the correct size and the location for placement of each bar. In case of doubt the inspector should check with his superiors. The importance for placing the reinforcement in the correct position, as planned by the design engineer, cannot be over-emphasized.

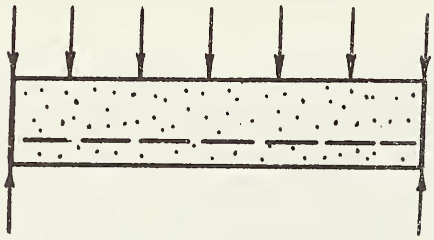
The following sketches which were reproduced from the "Handbook for Placing Reinforcing Steel" (by permission of the Concrete Reinforcing Steel Institute) are included to stress the requirement for proper placement of the primary steel for different structures and designs. These illustrations are distorted to some degree to show a convex shape which would result from the applied loads. The illustrations also show the location of the primary stress steel in the concrete member to resist the tension in the concrete caused by the applied loads.

Horizontal mats assembled in place should be tied at each intersection around the periphery of the mat, and at least every 4th bar. Vertical wall steel should be tied at least three times for each length of bar and more specifically at about every third intersection. Preassembled steel mats must be adequately tied to be rigid during the process of handling and placing. Bars must be supported by concrete blocks, chairs, bolsters or fabricated rebar spacers. Supports should hold the bars firmly and have adequate strength to carry the loads. Concrete blocks should be used to support steel on earth subgrade. Spacing of the blocks should be adequate to prevent steel from sagging or moving out of position when the concrete is placed.

Splices.
It is necessary to have splices in the reinforcement steel on most projects. For the strength of the steel to carry over from one bar to the other, a certain length of lap must be provided. The drawings should specify the minimum length of lap that will be permitted. Often this length will be specified in terms of diameter of the minimum size bars being spliced. Bars may be spliced by placing in contact for the required length of lap and wiring to maintain proper position. It is not desirable to splice bars at points of maximum stress.

Laps or butt joints formed by welding should not be approved unless specifically provided for in the contract.

Single Span-Simple Beam



LOADED MEMBER

SHAPE IT ASSUMES

Simple beams of one span supported as shown requires bars outside of curve (toward the bottom face) for the full length of the span.

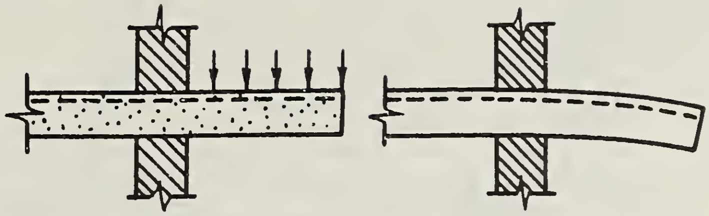
Continuous Beams

LOADED MEMBER

SHAPE IT ASSUMES

Beams that are continuous over more than one span, when loaded on top, tend to sag between the supports and hump over the supports. Steel must be placed in the bottom of the beam between the supports and in the top over the supports. Reinforcement for this type of beam is usually bent as a truss bar, and may be supplemented by stirrups.

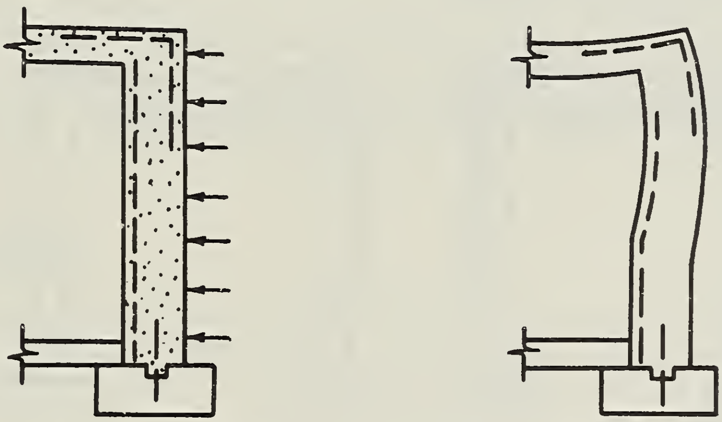
Cantilever Beams



LOADED MEMBER SHAPE IT ASSUMES

Cantilevered beams or slabs loaded on top want to bend down. In this case the steel must be placed in the top. Steel placed in cantilevers has to have anchorage, either extended straight thru or bent around a corner.

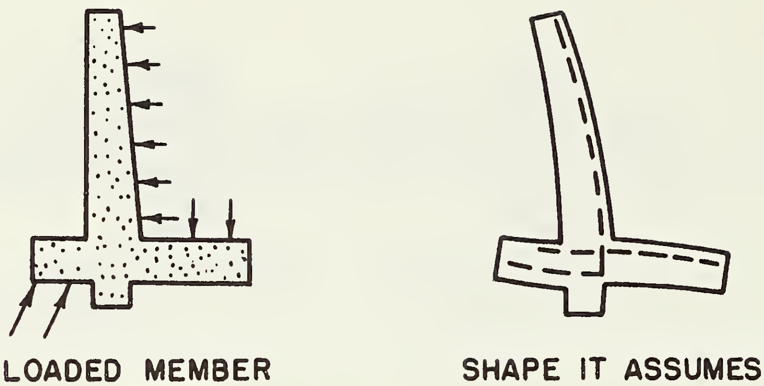
Walls



LOADED MEMBER SHAPE IT ASSUMES

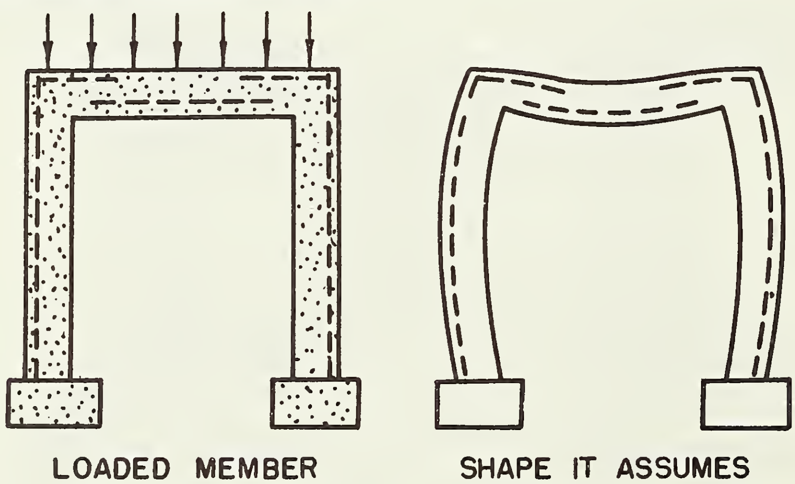
Walls supported by slabs at the top and bottom and resisting a horizontal load tend to bow inward. Thus the reinforcing should be placed toward the inside face of the wall. Depending on design, bars may also be required around the outside at the top corner junction, with the floor slab.

Retaining Walls



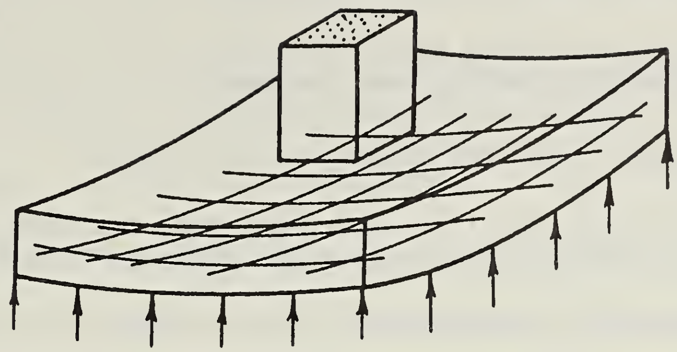
Retaining walls designed as cantilever require vertical steel to be placed toward the loaded face, and the anchorage must be placed as shown on the contract drawings.

Elastic (continuous) Frame



Structures designed as continuous frames and loaded on the top slab tend to buckle the side walls outward, so steel must be placed to the outside face of the side wall bending into the top of floor slab at corners; and along bottom face of slab.

Footing Slabs



Slabs which support a column load acting downward in the center, assuming uniform bearing capacity of the soil, which acts upward on the slabs, tends to fold the slab upward in all directions toward the corners. Reinforcing should be placed toward the bottom face of the slab and usually consists of a mat of steel with bars assembled in two directions and at right angles.

These few examples show the importance of knowing your structure and the drawings. Complete or partial failure of a structure quite often can be traced to improper placement of the reinforcement. The inspector cannot ignore his responsibility for seeing that the Contractor's steel setters properly place all steel reinforcement.

Ties and Supports

All reinforcement must be satisfactorily tied and supported in proper locations prior to starting a pour. Bar reinforcement may be held in place with wire or by various patented clips or chair supports. The method is not as important as the end result that the steel is held in position without distortion during the placing of the concrete. The amount of typing required depends on location and the amount of abuse the steel must take. Soft black, 16 gauge wire, is commonly used for tieing and many variations or kinds of ties from the simple snap tie to the more complex cross or figure eight tie are in use. For horizontal mats the snap tie is usually adequate. Horizontals bars placed in vertical walls may require a more rigid method, such as, a once and a half wrap around the vertical and then a diagonal around the horizontal bar with a tight twist. This type is fast and helps prevent the horizontal bar from slipping down.

Inspector's Check List

1. Determine that all materials meet the specifications for quality. Check for sharp bends or other damage.

2. See that the reinforcing steel is stored off the ground and in adequate space for sorting and checking.

3. See that adequate placing plans are available.

4. Make sure that the steel is free from mud, concrete, grease, oil, paint, loose rust or other coatings, prior to placing concrete.

5. Determine that the forms are to correct dimension, depth, width, and length.

6. Check all steel in place for size, proper bends, spacing, location, and correctness of installation. <u>See that steel is raised as required for proper position when subgrade is low</u>.

7. Determine that proper splices, ties, spacers, anchorage and cover exists.

8. See that bars are adequately supported with wires, metal chairs, spacers or concrete blocks of correct mix and strength.

9. See that no ungalvanized metal supports or reinforcement will be exposed in the concrete surface.

10. Do not permit ungalvanized metal supports to be used if they are in contact with earth subgrade.

11. Be sure multiple bars in beams are placed vertically over each other.

12. Require that reinforcements are placed at the designated dimension. Improper placement may cause failure.

13. Make sure wire fabric is lapped and tied as specified.

14. Do not permit the use of hooks or "lifters" to raise reinforcement in slabs.

15. See that steel is not displaced during the pouring operations.

16. Make sure that certifications have been received for all steel reinforcement.

17. Record all tests, quantities, and Job Diary entries.

<u>Note</u>: Each inspector should have access to the C.R.S.I. "Recommended Practice for Placing Reinforcing Bars" published by the Concrete Reinforcing Steel Institute, and should become familiar with the procedures that relate to the types of construction under consideration.

Structure Drainage

General.
Drainage requirements are dependent upon site conditions and the functional requirements of the structure.

The sound application of fundamental principles of soil mechanics is required for the design of adequate drainage systems.

Structure drainage systems may provide for:

(a) Relief of water pressures in the foundation.

(b) Drainage to expedite the consolidation of the foundation.

(c) Safe movement of water through foundations where soil has potential for piping.

(d) Drawing the phreatic water into the foundation or drainage system before it reaches the downstream slope.

(e) Relief of pressure to structure slab or wall sections.

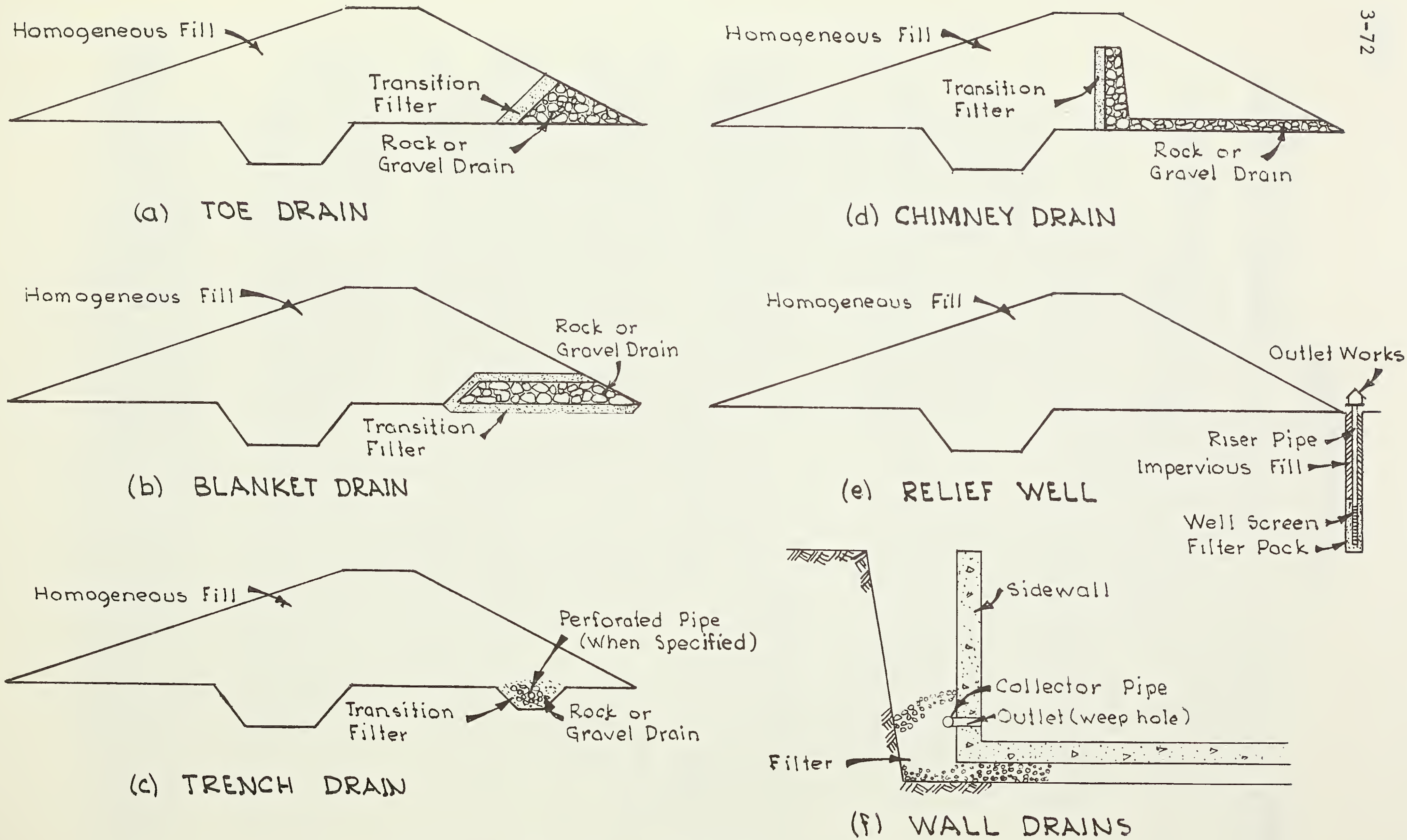
Types of Structure Drains.
Toe drain.--A toe drain is located in the downstream toe of an embankment and may consist of rock or sand and gravel or a perforated pipe. It may also be designed as an integral part of other types of embankment drainage systems. (See Figure 3-10 (a).)

Blanket drain.--A blanket drain consists of a layer of porous material, spread over a portion of the downstream foundation area of an embankment or the subgrade for concrete structures. The material may consist of rock and/or sand and gravel. (See Figures 3-10 (b) and (f).)

Trench drain.--A trench drain may be located in the downstream foundation area or in the embankment, either horizontally or vertically. The drain may consist solely of porous material or it may also contain a perforated pipe which discharges into an outlet pipe. A protective filter may be required as part of the drain. (See Figure 3-10 (c) and (d).)

Filter.--A protective layer of filter material may be required as part of the design for any type structure drainage system. A filter may be composed of zones of porous material, usually sand and gravel, in which the zones grade from fine to coarse in the direction of water flow, or it may be a mixture of properly graded material which will satisfy functional requirements.

Relief wells.--Relief wells provide effective control against uplift pressure generated by underseepage through pervious strata in the foundation under an embankment. Such wells are normally placed at or below the downstream toe of the embankment and consist of filter packed screen sections penetrating the pervious foundation strata under the



TYPE OF STRUCTURE DRAINS

Figure 3-10

structure and discharging through a riser pipe into a collector line. The spacing of relief wells, size of well, and the depth of penetration are related to the stratification and permeability of the foundation.

Relief wells which consist of bored holes or excavated pits backfilled with porous material may be used. These blind wells may outlet into trench, blanket or toe drains or into a special collector drain. (See Figure 3-10 (e).)

Wall drains.--A wall drain consists of a porous material, usually sand and gravel, that is placed adjacent to a structure wall to collect and facilitate drainage through weep holes in the structure wall. A wall drain may or may not include a collector pipe. (See Figure 3-10 (f).)

Cutoff Trenches.

Although not generally considered in the same category as the drainage appurtenances previously discussed, a cutoff trench may have a very definite effect on seepage flow and may influence the design requirements for other drainage facilities under or within the embankment. A cutoff trench may be built for one or both of two purposes, namely; (1) to reduce the volume of seepage beneath the dam through the foundation, and (2) to reduce the pore pressure in a relatively permeable foundation strata beneath the dam and downstream from the cutoff trench so as to reduce the hazard or possibility of failure due to flotation or piping.

Installation.

All materials for structure drainage and protective filters must be installed in strict compliance with the specifications. The inspector should determine that the materials meet the gradation requirements by performing a sieve analysis test as outlined on pages 4-150 and 4-152. The test data should be recorded on Form SCS-535B. Where unwashed manufactured materials are used, the amount of material finer than a 200 mesh sieve should be determined by the method described on page 4-152. The materials should be placed in such a manner as to avoid segregation of particle sizes, and to prevent mixing the filter or drain material with the foundation or adjacent embankment.

The methods for placing to prevent segregation are similar to the requirements for placing concrete. Materials should not have a free fall of more than 5 feet. Tremies, clamshell buckets, skips or other equipment should be used to satisfactorily place the material in deep excavations.

The use of a tremie is necessary where materials have to be placed in water.

In addition, the inspector should determine that the materials are compacted when required, and are placed to the neat lines shown on the drawings or as directed.

All drainage pipe, connections and weeps should be checked for location grade and alignment. Extra care is required when drain pipe is embedded in drain materials. All weep holes or other outlets should be checked after installation to determine that they are free from obstructions and will function as planned.

Inspector's Check List.

1. See that drains are constructed to the cross sections, lines, elevations and grades specified.

2. Be certain that drain and filter materials fully meet the specifications with respect to grading and grain size criteria, especially the allowable amount of fines, and that installation is in accordance with specified methods.

3. Make tests and record results as required.

4. Check adequacy of placing of drain material for segregation and contamination with unsatisfactory material.

5. See that perforated pipe meets specification requirements and is correctly installed with the perforations down. Check to see that perforated holes are open.

6. If C.M. pipe is used, determine that proper space exists between joints so coupling band will fit corrugations.

7. Check pipe to see that any damage to the pipe or coating has been properly repaired prior to placing filter or backfill materials.

8. See that necessary precautions are taken to guard against diplacement of the pipe during backfilling operations and that proper bedding has been provided.

9. Be sure that upper ends of drain pipe are capped, when specified, and the required guards are installed at the outlet ends.

10. See that backfill is evenly placed either side of pipe and compacted as specified.

11. See that all operations in connection with the construction, development, and tabulation of relief well data are performed in accordance with instructions.

12. Determine that necessary before and after surveys are made for drain and pipe material pay quantities.

13. See that certifications have been received and that all materials meet the requirements.

Pneumatically Applied Mortar

Pneumatically applied mortar, often referred to as "Shotcrete", "Airblown Mortar", or "Gunite", is mortar which is blown by an air jet onto the surface which is to be treated. Placing mortar by air is the most versatile of methods used for constructing concrete structures or surfacing other materials with concrete mortar. The method is adaptable to flat slabs, vertical walls and all increments of sloping walls, especially warped surfaces. The method may also be used to repair concrete or masonry surfaces or for coatings applied to steel pipe or shapes.

Preparation of Surfaces.

All surfaces should be thoroughly cleaned of loose material and all dirt, grease, oil, scale and other contaminations. The surface of concrete may require sand blasting or other methods of preparation to provide satisfactory bond for the pneumatic mortar. Earth subgrade should be shaped to grade and alignment and be well compacted. Steel reinforcement, forms, gaging wires and any other accessories should be well anchored.

All surfaces should be moistened immediately prior to placing the mortar. Wire fabric should be anchored by dowels grouted in drill holes when treating old concrete surfaces, or by chairs or other approved supports on earth subgrade.

Materials.

Sand.--The sand should be concrete sand which meets the requirements of contract, and graded within the range specified.

Uniformity of the fineness modulus, commonly maintained within the range of 2.50 to 3.30, is important for satisfactory operations. Likewise, the moisture content of the sand should be maintained within a good working range. If the moisture content is less than about 3 percent, the material does not feed uniformly, the sand and cement tend to separate and the amount of rebound increases. When the moisture range exceeds about 5 percent, frequent slugging may occur in the equipment and the discharge hose.

Cement.--The cement should be Portland cement which meets the requirements of the contract. Type I or Type II is commonly used. The cement should be carefully protected from moisture while stored on the job, and should be piled so as to permit access for keeping tally of the amount used.

Water.--The water used for mixing the mortar and curing should meet the requirements of the specifications.

Reinforcing.--The quality, surface preparation and placing requirements should be controlled as specified in the contract. Proper lap, anchorage and support for the steel is important since there is considerable impact to the steel as the mortar is placed.

Equipment.

The following procedures are pretty much standard for processing and placing pneumatically applied mortar:

1. A standard concrete mixer is used to dry mix the sand and cement.

2. The dry mix is placed in a mechanical feeder or pressure chamber. For larger operations, two pressure chambers are used to maintain continuous feed.

3. The mix is fed out of the pressure chamber into a delivery hose by a feed wheel or screws. All operations are actuated by air pressure.

4. The dry mix is forced through the delivery hose to the placing nozzle under air pressure. The placing nozzle acts as an orifice. It is assembled with a special surrounding ring or manifold which sprays water radially into the jet of mixed sand and cement. The water is supplied to the placing nozzle, under pressure, by a separate hose.

5. The mixture of sand, cement and water moves as a jet to the area to be treated.

Mixer.--The initial mixing equipment should be adequate to thoroughly dry mix the sand-cement in a continuous supply. Thorough mixing is essential to good quality mortar. The mixing time and the amount of time allowed prior to placing the mix should be as specified. It usually taked 1 1/2 to 2 minutes mixing time to produce a good uniform product. The materials may stick to the mixing blades, requiring frequent cleaning of the mixer to maintain uniformity.

Pressure chamber.--The vertical double-chamber type is the most common. The upper chamber is charged and automatically releases into the lower chamber when it is empty, thereby maintaining a continuous supply to the feed hose.

After the upper chamber is emptied, the pressure is released for recharge. The lower chamber assembly contains metering equipment to feed the mix into the delivery hose. Cleaning of caked material from the interior of the drums, feed assemblies and valves should be required as necessary to maintain uniform delivery to the placing nozzle.

Hose and placing nozzle.--Uniform pressures at the nozzle are necessary. Experience indicates that the best conditions for placement result with a hose length of less than 100 feet. Additional length may be used if the pressure is increased to maintain proper nozzle velocity.

Air pressures should be maintained within the specified limits.

The pre-mixing type of placing nozzle, which has a perforated water feed ring built integral with the nozzle and distributes the water

through the mix, gives the most uniform performance. Unsatisfactory mixing often may be traced to excessive wear in the nozzle liner.

Air compressor.--The air supply should be adequate to furnish without interruption the volume and pressures specified for the longest length of delivery hose. Requirements for compressor capacity should also allow for blowing away rebound and other incidental uses.

Water pumps.--Satisfactory operations require that the water pressures, as well as the air supply, be uniform and free from surges. The pumping equipment should have adequate capacity to supply the required volume at pressures at least 15 pounds in excess of the requirements for placing.

Placement.
The success of pneumatically applied mortar can be credited to a great degree upon the experience of the nozzle man. Three men usually make up a crew--the nozzle man, the machine operator, and a man to clear away rebound. They all should be experienced and work as a team. The machine operator usually regulates the pressures for air and water and the rate of feed of the mix so as to produce a uniform mortar at the nozzle. The rebound man, besides clearing away loose materials, aids in moving the hose and other placing details.

The nozzle man places the mortar systematically to the requirements of the contract. He must add the proper amount of water and position to the nozzle. The nozzle should be about 3 feet away from the treated surface, space permitting, and nearly normal to the surface. The nozzle should be manipulated to secure maximum compaction with the minimum loss of material. The layer thickness and other placing details should be checked to determine that the requirements of the contract are met. Special attention should be given to restricting the thickness of each layer placed on steep slopes to prevent sloughing of the freshly placed mortar. The uniformity of the surface and appearance are important. A good nozzle man can complete the work to the required section with a minimum amount of fill in and repair, providing adequate finish strips or gaging wires are set ahead.

Placing operations should be suspended if high wind occurs which separates the mixture at the nozzle. Pneumatic mortar should not be placed on a frozen surface or when air temperatures exceed the maximum specified.

Curing.
Adequate and immediate cover of the finished surface is critical for pheumatic mortar since the product is placed with a relatively low water content. This is especially important during periods of extreme heat and high wind.

To prevent damaging cracks and separation for thin sections, the curing medium specified should be applied just as soon as the surface will permit. If water is applied, a short delay will be required to prevent damage. Small areas of color variation will indicate readiness. If

sealing compounds are used, they should be applied as soon as the placing operations are complete.

Tests and Reports.

Test cylinders molded with hardware cloth forms should be made as directed. Each cylinder should be properly marked for identification and the required reports prepared. Other tests, such as sieve analysis of the sand, and moisture determinations may be required to aid in accomplishing a satisfactory job.

A record should be maintained of the type of equipment, size and lengths of feed hose and the operating pressures, along with production rate.

Any shutdown, equipment failure, or other delay should be noted with the reasons for the delay.

Inspection Check List.

1. Determine that earth subgrade is shaped as shown on the drawings and is firm and moist.

2. Make sure surfaces of concrete or other materials are clean and moist prior to placing mortar.

3. See that the reinforcement is properly placed and supported.

4. See that strike offs or guide wires are installed for thickness control.

5. See that the placing equipment is of adequate capacity and in good operating condition.

6. Determine that the materials and the mix meet the requirements.

7. Make sure that satisfactory batching equipment is available.

8. See that the sand-cement is dry mixed for the specified time.

9. See that delivery hose length and pressure is in accordance with the specifications.

10. Make sure water pressure exceeds feed line pressure.

11. See that all equipment is kept free from caked materials and that delivery of mix is uniform.

12. See that mortar is applied in uniform layers, and that mortar is not permitted to set prior to placing successive layers.

13. Make sure all surfaces are moistened just prior to placing mortar.

14. Check for excessive rebound (20-40 percent normal). Do not permit reuse of material.

15. Determine that the finished surface is uniform and meets the tolerances specified.

16. Check for sand or slough pockets - be sure they are cut out and repaired.

17. See that weep holes or other specified drains are properly installed and are free from obstruction.

18. See that surface of finished mortar is cured as required.

19. Do not permit operations when subgrade is frozen or air temperatures are below the minimum specified.

20. Make sure all tests are performed as called for in the contract or as otherwise directed.

21. See that certifications have been received, and that all materials meet the requirements.

22. Record all tests, quantities, and Job Diary entries.

Pipe Structures

Delivery and Storage.

Material check.--All types of pipe should be visually inspected upon delivery. Allconcrete and clay pipe when dry and when stood on end should give a clear ringing sound when tapped with a light hammer. Drain tile, clay sewer pipe, and non-reinforced concrete pipe should be inspected for imperfect manufacture as evidenced by cracks, blisters, warps, and large variations in shape. Reinforced concrete pipe should also be inspected for cracks passing through the shell and transverse cracks around the periphery of the pipe at the joint locations. The inspector should also check for indications of imperfect mixing or molding, spalls, exposure of circumferential reinforcement, and evidence of a honeycombed area. Further, no pipe should be accepted for use in the work without proper certification.

All pipe sections should be marked with the manufacturer's name, plant location, and the grade of pipe. Markings on concrete pipe may be stenciled on the pipe, but clay pipe will be marked by indentation on the pipe exterior. Reinforced concrete pipe having elliptical reinforcement and all bevel joints should be marked "TOP" on the outside of the pipe to facilitate placement.

Pipe sections that do not meet specifications should be clearly marked as rejects. All rejected pipe should be marked by the inspector in a manner that will not impair its salvage value by the contractor.

Unloading and handling.--In transporting pipe to the job site, care should be used in unloading so as to prevent damage to the pipe. Concrete pipe should not be rolled from trucks or down embankments in such a way that the pipe gets out of hand and rolls without control. If the sections of the pipe are moved along the ground by pushing with bulldozers or tractors, great care must be taken not to damage the pipe. Corrugated metal pipe should not be pushed or dragged over gravel or rocky surfaces. Injury to the coatings may adversely affect the durability of the pipe. Pipe should never be lifted by means of a sling running through the pipe because the applied pressure may damage or break the ends.

Storage.--Pipe delivered to the work site should be stored in an accessible location as near as possible to the place it will be installed but not to interfere with equipment movements and other preparatory operations. To avoid possible damage, pipe should never be stacked in ricks. Corrugated metal pipe having paved inverts should be stored in position to prevent flow of the asphaltic invert lining.

Inspection of Material.

The inspector should give attention to the following items in connection with the inspection of pipe materials:

Diameter.--Check all pipe to see that it is of the diameter specified.

Wall thickness.--Make sufficient measurements to ascertain that the wall thickness fully meets the specifications for the grade and type of pipe specified.

Concentricity.--All pipe must be uniform and concentric; otherwise, the ends will not fit properly to develop a watertight joint and damage to the end of the pipe is likely to occur when it is connected. Any pipe that lacks uniform roundness should be rejected. The specifications should be checked for permissible tolerance.

Joints.--Joints should be carefully checked for soundness and uniformity. Thickness and length of bell-and-spigot or tongue-and-groove connections must conform to the specifications. A template may be cut from cardboard or other materials to check clearance. Any joint that has been damaged through careless handling should be rejected.

Fittings.--All fittings should be of the type, size, and kinds of material called for in the specifications or as shown on the contract drawings.

Perforated pipe.--Perforated pipe used for embankment drains should be checked for size, length, type and diameter and size and spacing of perforations to ascertain that it fully meets the specifications.

Coating.--Premolded metal pipe should be checked for adequacy of surface coating with bituminous asbestos bonding, or other specified material. The coating on perforated pipe should also be inspected to ascertain that the drain holes are open.

Other materials.--Joint materials, such as jute, asphaltic joint compounds, and premolded rubber gaskets, when required, should be checked for adequacy and conformity with the specifications.

Installation.

Excavation and foundation preparation.--The pipe should be laid to the line and grade specified. Unless the methods of performing the excavation are prescribed by the specifications, the inspector should not interfere with or dictate the methods to be used by the contractor. It is to the contractor's advantage that the excavation be performed in as short a time as possible for the pipe laying operation to reduce the chances of caving or intervening storm damage.

Foundations requiring the placement of compacted backfill and reexcavation should be constructed to the lines and grades shown on the drawings. Compaction tests should be made and test results recorded as required. When rock occurs at shallow subgrade elvations it should be excavated as necessary to provide the minimum backfill depth specified, and to eliminate irregularities in the rock profile that would induce dangerous differential consolidation stresses in the pipe. Rock foundations requiring the placement of concrete bedding or cradles should be excavated and treated as specified to provide satisfactory bond with the rock materials, and the required concrete thickness. Earth and weathered materials should be removed from the rock surface and from

cracks and crevices in the rock. Additional cleaning operations, such as the use of air, water, and brooming to expose a clean surface may be necessary to meet the prescribed requirements.

The specifications will usually indicate a minimum size trench necessary for installation of pipe, or placing and removal of concrete forms used in conjunction with the pipe installation. When the specifications prescribe a maximum width of trench, this must be strictly adhered to because of the effect of loading on the pipe. The following inspection items are pertinent to this phase of the work:

1. Give careful attention to the inspection of all trench excavation and backfilling to insure it is done in accordance with the specifications.

2. See that the trench excavation begins at the outlet end of the pipe line and proceeds upgrade to protect the work from flooding, unless otherwise specified.

3. Stress the need for necessary safety precautions if conditions are conducive to caving or other hazards exist. All shoring and bracing must meet the requirements in the contract.

4. See that trenches or foundations in rock are excavated to the required depth below grade and backfilled and compacted with select material as specified.

5. See that trenches having unstable subgrade material are over-excavated, backfilled with select material, and properly compacted to support the cradle and pipe.

6. Insist that adequate facilities are provided for dewatering pipe foundation as specified.

Alignment and grade.--It is essential that pipe conduits be placed accurately to line and grade. It is also mandatory that any specified camber in the line be provided in strict conformity with the contract requirements. Although the contractor may choose the method whereby he obtains true line and grade, the inspector must satisfy himself that the methods used give proper results.

Bedding.--The type of bedding will normally be prescribed in the specifications or shown on the contract drawings. The various types are briefly described below:

1. <u>Concrete Cradles</u> - Pipe may be encased in concrete or supported by a plain or reinforced concrete cradle. The pipe should be supported on precast or "poured in place" concrete blocks preparatory to pouring the concrete cradle.

2. <u>Concrete Base Slab or Platform</u> - Pipes placed on a concrete slab or platform are secured by wedges consisting of material that will bond and integrate with subsequent concrete pours.

3. Concrete Bedding - The bottom of the trench or excavation is shaped as shown on the contract drawings and concrete thoroughly tamped, rodded, or vibrated around the bottom of the pipe. Caution must be exercised to guard against displacement of the pipe due to uplift pressure.

4. Earth or Granular Material - The bottom of the trench in earth should be excavated to grade, allowing for shaping to fit the outer circumference of the pipe, as shown on the drawings.

   For granular bedding the excavation should be made to the depth shown on the drawings, or as directed, and backfilled to grade allowing for consolidation and shaping to fit the pipe.

   The pipe should bear against solid undisturbed earth, compacted earth or granular material as specified for its entire length.

Laying pipe.--The pipe should be placed to the lines and grades shown on the drawings and as staked. The inspector should be present when pipe is being laid to insure that satisfactory methods of handling, joining, aligning, and treating joints are employed. It is important that the contractor provide competent workmen who are experienced in this phase of work. Figure 3-11 shows typical methods of coupling concrete pipe. For pressure pipe it is desirable to complete each joint individually as the sections are placed, rather than complete a number of joints at one time.

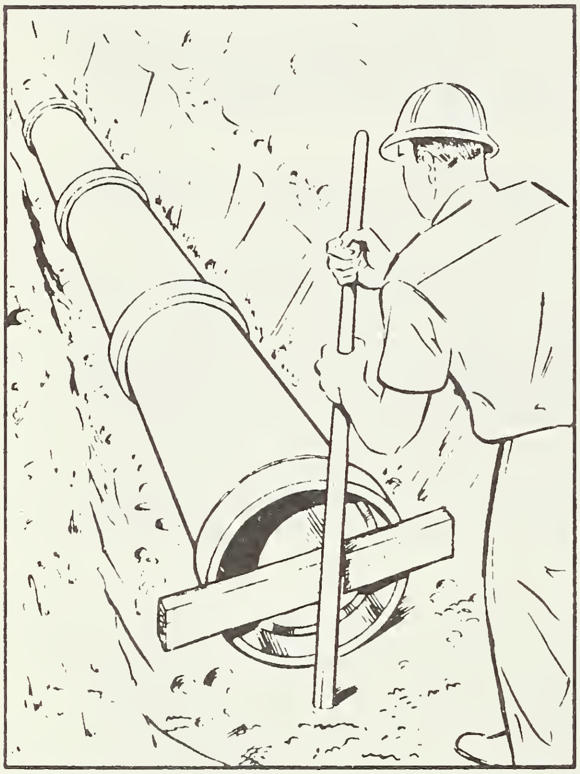
Each joint made with a rubber seal ring should be checked with a feeler gauge to determine the correct position of the seal ring. Closure of pipe joints for principal spillways should be made in the following sequence, (1) close joint to 1/2" maintained by inserts, (2) check position of rubber gasket, (3) remove inserts and make complete closure, and (4) check remaining gap as specified. All measurements are made from inside the pipe when pipe size will permit.

Some types of pipe, such as perforated pipe and elliptically reinforced concrete pipe, have to be properly positioned. Particular care is required with such types to make sure that they are installed correctly. Reference marks should be legibly placed along the top centerline of elliptical pipe to facilitate correct setting. Unless it is otherwise specified, perforated pipe should always be laid with the perforations at the bottom.

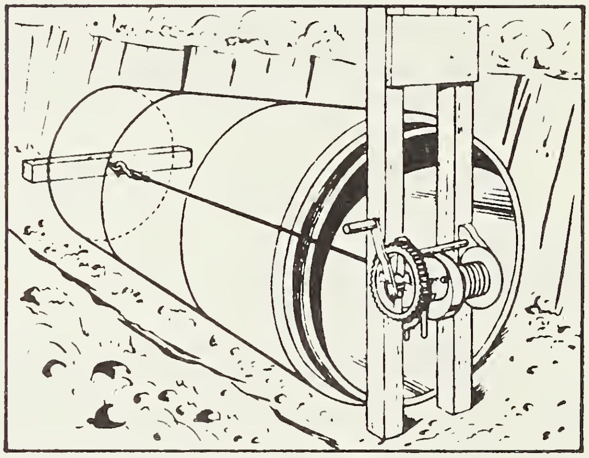
Corrugated metal pipe should be laid with the inside circumferential laps pointing downstream. Longitudinal laps should be at the sides or quarter points, but not on the bottom. To insure proper positioning of the coupling bands on corrugated metal pipe, it is important that a clear space of approximately one (1) inch exists between the abutting ends of the pipe sections. Failure to provide this gap may cause the grooves of the coupling band to missmatch the grooves of the in-place pipe and tightening of the coupling band fasteners will not result in a stable tight joint. Connecting bands should be tapped during the

TYPICAL COUPLING METHODS

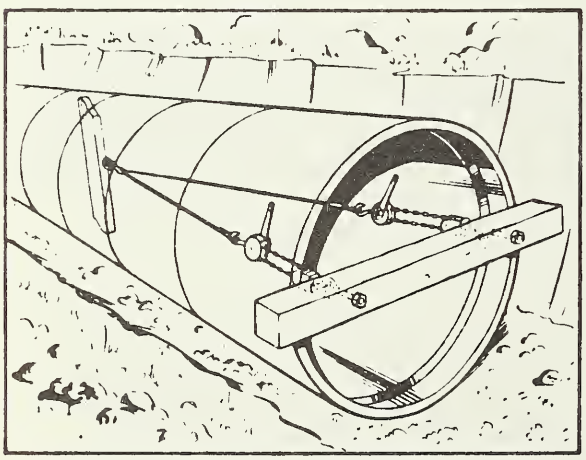
The illustrations below depict a few of the more common methods of satisfactorily coupling rubber jointed concrete pipe.



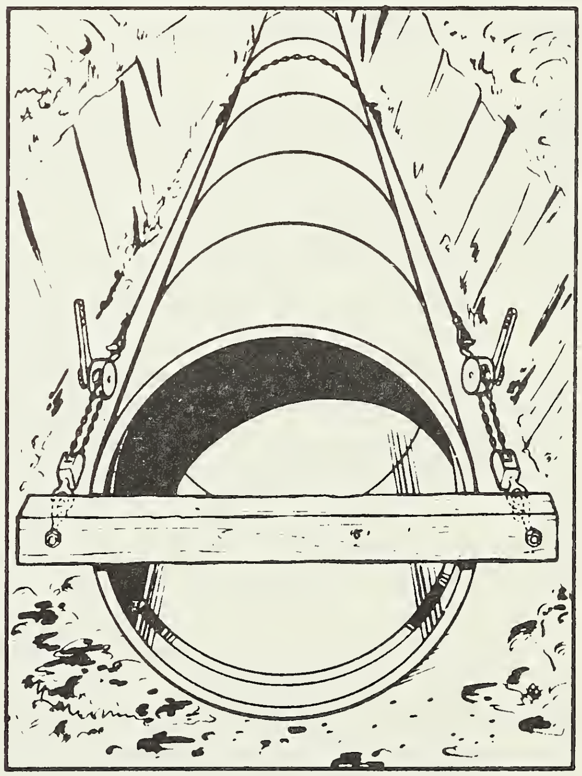
Small bore pipe may be coupled manually, using a cross-member and bar.



Suggested design for winch and cross-members, using an inside pull (manhole to manhole).



For large bore pipe the double come-along inside the pipe is used with a cross-member and deadman.



For an evenly distributed pull, a double come-along is used on the outside with a cross-member and tail-hold.

Figure 3-11

tightening process to seat the band. Corrugated metal pipe should be checked at the time of installation to determine that the strutting, as required, is properly positioned and of adequate strength to withstand the loading of the backfill or embankment. A careful check should be made of all pipe coatings to determine that damaged areas are properly treated prior to back filling. The detailed methods of making up the joints will normally be prescribed in the specifications, or shown on the contract drawings. The inspector should determine that these methods are carefully followed and that satisfactory, watertight, truly aligned, smooth joints are obtained and that camber, if required, is provided. For concrete pipe the inside face of the mortar joint should be carefully wiped smooth after it is completed, and necessary precautions should be taken to protect mortared joints during the prescribed curing period. Concrete mortar should not be permitted to enter pipe joints which are designed to be flexible. Flexible type joint gaskets should be checked after each joint is made to determine that the material is in proper position. Open ends of pipe lines should be kept closed when work is not in progress.

Backfill.--Prior to compacting backfill under corrugated metal pipe or steel pipe, precautions should be taken to weight the pipe to prevent raising it above grade.

In backfilling around pipe structures, selected material from excavation or borrow should be uniformly placed along either side of the pipe in layers not exceeding four (4) inches in depth unless otherwise provided, and compacted thoroughly by hand or mechanical tampers to the requirements of the specifications. Heavy construction equipment should not be permitted to operate within two (2) feet of any part of the unprotected structure or to cross over it until it has been covered by at least two (2) feet of compacted fill. If concrete is an integral part of the pipe conduit, the specifications should be checked for curing period and backfill requirements.

<u>Field Test</u>.

The equipment and procedures used for field testing pressure pipe lines should conform with the requirements of the specifications. The specific reaches of the line to be tested, the test pressure and the method for testing should be as set forth in the contract.

Special precaution should be taken to determine that each detail of the test is performed as required since the results will be used to determine acceptance of the pipe structure.

Unless otherwise specified, the contractor will provide all necessary equipment and facilities for making the tests.

Inspector's Check List.

1. Make a visual inspection of each section of pipe, check for defects in manufacture and damage caused by handling. Plainly mark all rejects.

2. Determine that the specified sizes, thicknesses and quality of pipe and fittings have been delivered.

3. See that the excavation conforms to the lines and grades specified.

4. Determine that trenches are cribbed, shored and braced as required for safety.

5. See that foundation materials and the required preparations are adequate.

6. Check that each section of pipe is prepared, placed, joined, sealed, and supported as specified.

7. Gauge all rubber gaskets for proper position as concrete pipe joints are made. See that the pipe ends making the joint are closely fitted as required.

8. Determine that coupling bands on corrugated metal pipe are properly positioned and pulled tight.

9. See that pipe is strutted as required before placing embankment, and that struts are removed at the time specified.

10. Check that damaged coatings and other untreated areas are properly coated prior to placing backfill.

11. See that joint seal material, mortar bands and other joint treatment are placed and cured as required.

12. Determine that the quality of the backfill, the placing and compacting meet the requirements.

13. Make compaction tests on foundations and backfill and record all test data.

14. Check for movement of pipe while backfill is placed. Record "in-place" profile of pipe conduit as directed.

15. Maintain complete record of all field pressure tests, check that methods and equipment are as specified.

16. Determine that certifications have been received prior to placing pipe and that all materials meet the specifications.

17. Record all tests, quantities, and Job Diary entries.

Metal Work

General.
All metal materials must be of the grade, quality, and size specified.

Unless modified in the contract, the procedures to be followed in the fabrication and field installation will be as outlined in "Specifications For The Design, Fabrication and Erection of Structural Steel For Buildings", as adopted by the American Institute of Steel Construction.

Field personnel should become familiar with this reference specification for detail information.

Delivery and Storage.
Material check.--Upon delivery, all materials should be checked for quantity and for evidence of damage or inferior workmanship.

Unloading.--Structural steel should be handled carefully to avoid unwarranted strains in impact. The inspector should watch particularly for such types of damage as tearing off or distortion of clip angles, buckling of loosely attached secondary members and denting or nicking of flange angles, machined faces, or bearing surfaces.

Storage.--Steel materials should be stored above the surface of the ground on platform skids or other supports and should be protected from mechanical injury and surface deterioration.

Inspection of Materials.
Dimensions.--The contract drawings, specifications (and shop drawings when required) provide dimensions of all materials and complete details necessary for fabrication. Any deviation from the drawings and specifications which results in a reduction of structural strength or quality or that will cause difficulty in field erection are justifiable reasons for rejection of the material.

Workmanship.--Workmanship and finish should be equal to the best general practice in modern structural shops or field erecting procedure.

Punching, drilling and reaming.--The inspector should ascertain that rivet and bolt holes are prepared in the manner prescribed and within the limits of accuracy as to size and position for each part of the work. He should make sure that punching, drilling and reaming are done with the tool normal to the surface and without deformation of the member, and that multiple plies are clamped tightly together so that no cutting or burrs were forced out between the plies. He should see that all outside burrs are removed. Holes may be punched if the thickness of the material is not greater than the nominal diameter of the rivet or bolt plus 1/8 inch. The holes should be either drilled or subpunched and reamed. Holes should be drilled 1/16 inch larger than the nominal diameter of the bolts unless otherwise specified. Holes for turned bolts should be drilled or reamed truly cylindrical and

not larger than approved tolerances. Drilling or reaming for turned bolts should be done after the parts are assembled or connected if practical.

Riveted work.--All parts of shop riveted members should be well secured and rigidly held together. After being driven, all rivets should be tight and their heads should be in full contact with the surface. Rivets should be hot-driven, and the finished heads should be approximately hemispherical in shape and of uniform size throughout the work for the same size rivet, full, neat and concentric with the holes. Each rivet should be checked by tapping with a light hammer. A clear ringing sound indicates the rivet is tight.

Bolted work.--The inspector should verify that bolts and nuts installed in the shop are of the class, finish, form and size specified and that bolts are used only where specifically permitted by the specifications, except for temporary bolting for shipment. He should make certain that locknuts and washers are tightened without overstressing the bolts, and, if required, that threads are nicked or upset to prevent the nuts from backing off.

Welded work.--All surfaces to be welded should be free of loose scale, slag, grease, paint, and any other foreign materials, except mill scale which will withstand vigorous wire brushing. Preparation of edges by gas cutting should, whenever practical, be done with a mechanically guided torch. Welding should be done only where specified on the drawings and by qualified welders.

Cleaning.--All steelwork should show evidence of thorough cleaning of all loose mill scale, rust, spatter, slag or flux deposits, oil, dirt and other foreign matter.

Shop painting.--All steelwork should be given one or more coats of approved metal protection paint, or other specified protective coating applied thoroughly and evenly and well worked into the joints and other open spaces. All paint should be applied to dry, clean surfaces. (The above does not apply to edges or surfaces of metal that are to be welded or embedded in concrete.)

<u>Erection</u>.

Safety precautions.--The contractor should at all times exercise reasonable precautions for the safety of all employees on the job and should comply with all applicable provisions of federal, state, and municipal safety laws, and building and construction codes.

Tolerances.--The inspector should make sure that all steelwork conforms accurately to the dimensions shown and to the quality of details and workmanship specified; that punched, reamed and drilled holes match within the tolerances prescribed for the class of work specified; and that all work is complete and true in alignment.

Correction of errors.--The inspector should be alert to detect any errors in fabrication or assembly and to obtain their correction, preferably before the steel is erected and, in any case, before the work is finally riveted or welded.

Erection and alignment.--The inspector should require that all steel, as it is erected, be held and supported adequately to guard against collapse resulting from abnormal winds or erection loads and should make sure the contractor erects and bolts up promptly sufficient bracing and secondary steel to maintain the stability of the work. It is necessary that sufficient steel be erected before final alignment is started to assure that the part aligned will not be thrown out of alignment by the successive erection of adjacent parts. Final alignment should be started as soon as possible to obviate the possibility of accumulated errors.

Bolting.--The inspector should require the installation of sufficient temporary bolts in all connections to guarantee that the steelwork will hold its alignment during final riveting or welding operations. Particular attention should be given this phase of the work when it is necessary to remove guys or other temporary braces or supports before the final riveting or welding is accomplished.

Field riveting.--Adequate facilities should be provided for heating, passing and driving rivets. All rivets should be uniformly heated, without burning and driven while hot. All rivets should be checked individually by tapping for tightness and by visual inspection to make sure that heads are full, concentric, and properly shaped. If heads are repeatedly undersize or oversize, the contractor should be instructed to provide longer or shorter stock. Rejected rivets should be clearly marked and removed without damaging the members or the holes. When authorized, the inspector should require reaming or drilling of elongated or distorted holes and replacement with oversize rivets.

Field welding.--Inspection of field welding of structural steelwork is mainly visual and requires a thorough knowledge of accepted techniques and of the difference between satisfactory and unsatisfactory welds. In particular, the edges or surfaces to be welded must be correctly prepared, shaped and cleaned; the members must be held tightly together with joint clearance exactly as specified; the size and type of rod must be suitable and the welding machines and equipment in good operating condition and of adequate capacity; and finally, the work should be performed by qualified personnel.

Field painting.--(a) Materials. Requirements for field painting will be as outlined in the specifications. The inspector should make sure that the paint supplied fully complies with the contract requirements.

(b) Workmanship. The inspector should see that the prime coat is retouched wherever it has been marred and that all surfaces to be painted are thoroughly clean and dry. Paint should be sprayed or brushed evenly over the face of the surface so as to prevent running or beading. Each coat should be dry before application of another coat.

Inspector's Check List.

1. Determine that required certificates have been received and that all materials and shop fabrication meet the requirements.

2. Make sure all members are of the dimensions and shape specified.

3. Check condition of shop paint coating. Require touch up of abraided spots.

4. See that steel is stored and protected from weather as specified.

5. Do not permit straightening of sharp kinks in warped or bent steel. Only minor straightening should be permitted.

6. Check that anchor bolts are of the proper size and located to line and grade.

7. Check the contractor's proposed methods and erecting equipment. Advise him of any conditions considered to be unsafe.

Bearing Plates or Frames.

(1) See that top of concrete is clear of dirt or other foreign matter.

(2) Make sure bearing plates are set at proper line and level or slope, and firmly anchored over metal wedges, shims and/or setting nuts.

(3) Shims should be steel plates made from varying thickness.

(4) Determine that dry pack bedding mortar is properly rammed into place between bearing plate and top of concrete.

(5) See that exposed edges of mortar bedding are properly cured.

Alignment and Support.

(1) See that all steel members are accurately fitted, leveled, guyed, and adequate temporary connections made before permanent connections are completed.

(2) Check guys and supports for size and adequacy of anchorage. All guy lines must be taut.

(3) Do not permit rough handling of material such as heavy pounding with sledges.

(4) Do not permit damages or distortion of the metal with drift pins used to align rivet or bolt holes.

(5) Do not allow use of cutting torch for correcting fabrication errors on any major member.

Field Assembly.
Riveted connections.--

(1) Do not permit the burning of misaligned or undersized rivet holes.

(2) Check matching of rivet holes. Ream mismatched holes for oversize, if feasible; otherwise, reject the material.

(3) Do not accept rivets having pitted or pock marked heads. This indicates overheating or burning of the rivet.

(4) Watch for marks or deformations in the steel around the rivet, indicating poor workmanship or improper equipment.

(5) See that rivets are at proper heat to form uniform heads.

(6) Check all rivets for looseness and movement by tapping with a hammer - should have no movement and give a clear ring. Mark rejects plainly for removal.

(7) Do not permit reheating and reforming of defective rivet heads.

(8) Require that rivets be painted after driving and touch up any other damage to shop coating.

High Strength Bolted Connection.

(1) High strength bolts are identified by three radial marks on the head and three long indented marks on the nuts. The bolt is used with two high carbon steel washers. Check that ordinary nuts and washers are not being used.

(2) Check surfaces of metal to be bolted for dirt, oil, loose scale, burn pits or other defects that would prevent solid seating of the parts.

(3) Check bolt tension by use of torque wrench.

(4) Do not permit use of bolts and rivets in the same connection.

(5) Determine that required lock washers are installed.

(6) Check paint requirements for bolts before and after installation.

(7) Do not permit the burning of misaligned or unfair holes. Poor matching of holes should be considered as justification for rejection.

(8) Turned or rivet bolts used in reamed holes and ribbed bolts should be checked same as other bolts. Make sure ribbed and rivet bolts are used without washers.

Welded Connections.

(1) See that surfaces to be welded are free from loose scale, slag, rust, grease, paint or other foreign material.

(2) Make sure that joint surfaces to be welded are free from fins and tears.

(3) Determine that all the required welds are made at the locations specified.

(4) Check finished weld for size, length and workmanship with respect to contour and appearance of surface, surface defects, craters, undercutting, overlapping edges or cracks.

(5) Discourage over-welding either in size or length. Such practice may cause distortion.

(6) Do not permit the burning of holes for attachment of supports.

(7) Do not permit cutting of steel members for passage of conduits, pipes, etc., unless shown on the drawings or approved otherwise.

Final Painting.

(1) Prior to final painting, make sure the installation is complete, all steel surfaces are free of foreign matter, and the prime coat touched up including rivets, bolts, areas of welds and cut surfaces.

(2) See that paint is applied uniformly, only to dry surfaces.

(3) Make sure paint materials are not applied when temperatures are below 45° F. and that protection is provided as specified until paint is dry.

(4) Do not permit painting of steel that is to be encased in concrete.

Records and Tests.

(1) Record all tests, quantities and Job Diary entries.

Timber Construction

General.

All timber materials to be used must be of the grade, quality, size and quantities specified.

Inspection and Grading.

Grade-marked and trade-marked lumber.--Lumber is generally graded according to the standard grading rules of the association or producers of the kind of lumber purchased, or of the inspection agency of that association. These grading rules define the imperfections that affect the quality of the lumber and determine grade limitation.

Marking and stamping.--The specifications prescribe that the lumber conform to certain standard grades of the appropriate lumber association. The inspection should be made in accordance with the standard grading rules of the association specified in the contract. In the case of special woods, grading of which has not been standardized by any association, inspection and grading must be in accordance with the requirements of the contract specifications. All materials should be marked or stamped so that they may be easily identified as to quality, grade, and, if treated timber is used, the method of treatment and retention per cubic foot should be indicated by markings, or by treatment plant report.

Characteristics affecting grade determination.--The following are brief descriptions of typical defects and blemishes that are evaluated in determining the grade of lumber. Definitions and standards of measurement and classification of such imperfections vary with the kinds of lumber and with each association. The inspector should be thoroughly familiar with the details of the applicable inspection and grading rules. Descriptions of some of the defects which influence grades in lumber are as follows:

(1) Checks are lengthwise grain separations that take place during seasoning. They usually cut through or across the growth rings. Checks are further described by type, location, and size.

(2) Decay of wood, also called rot or dote, is the disintegration of the organic substance of the wood by the action of destructive fungi. There are various stages of decay. Incipient decay changes the color, but may not seriously affect the strength or hardness of the wood or make it entirely unfit for use. Advanced decay results in the complete breakdown of the wood structure, leaving it soft, spongy, or punky, and entirely useless. Peck is a form of pocket rot that occurs in cypress, leaving longitudinal holes.

(3) Holes in lumber, from any cause, affect its utility and grading. Holes are classified as pinholes, medium holes, and large holes. Grading limitations are frequently based on the percentage of waste involved when no holes are permitted in the finished work.

(4) Knots are sections of limbs that have become embedded in the trunks of the tree and are cut through in manufacturing the lumber. Knots are generally classified as to size, as pin, small, medium, or large knots; as to form, as round if cut crosswise or as spike if cut lengthwise; as to growth, as intergrown, watertight, or encased; and as to stability, as tight, fixed, or loose.

(5) Mismanufacture includes defects and blemishes produced in manufacturing the lumber, such as chipped, loosened, raised, or torn grain; skips or unsurfaced areas in dressed lumber; miscut or variations in sawing from the true line of cut; machine burn or gouge; mismatch resulting from uneven fit of adjoining pieces when placed; and insufficient tongue, groove, or lap.

(6) Pitch is an accumulation of resin in the cells of the wood of pine, fir, or spruce, and usually appears in a more or less irregular patch or in streaks or pockets. Pitch is judged by visual inspection as light, medium, heavy, or massed. Pitch streaks and pockets are judged by their size and distribution in a piece of lumber.

(7) Pith is the small soft core in the center of a log. The combination of the pith and wood immediately around it, which is discolored and may contain small checks, shakes, or pin knots, is called the heart center.

(8) Shakes are lengthwise grain separations between or through the growth rings. A ring shake occurs between the growth rings and is cylindrical in form; a pith shake is radial, like a check but is widest near the pith. Shakes may be classified by size as fine, slight, medium, or open; or by extent, as through (extending from one surface to another), round (when they completely encircle the pith), or cup (when they do not completely encircle the pith).

(9) Split is a lengthwise separation caused by the tearing apart of the wood cells. Splits are classified as short, medium, or long.

(10) Stain is a discoloration, other than the natural color of the wood, occurring on or in lumber. It is classified as light, medium, or heavy.

(11) Wane is bark, or the lack of wood from any cause, on the edge or corner of the lumber. It is classified in some grading rules as slight, medium, or large by dimensions of cross section and the proportion of the length and thickness of the piece affected.

(12) Warp is any variation from a true or plane surface. It includes bow, which is deviation flatwise from end to end; crook, which is deviation edgewise from end to end; and cup, which is deviation flatwise from side to side.

Grading provisions.--Lumber is a natural material and is, therefore, subject to variations that cannot be evaluated precisely. The grading of lumber is not an exact science, but a matter of expert judgment based on intelligent and reasonable interpretation of the rules. The following provisions are important:

(1) Grading Face - The rules generally specify which face of the lumber shall be considered as the graded face. Dimension, heavy joists, and timbers are graded from the poorest face. Yard lumber, rough or surfaced, is graded from the better side, except that lumber surfaced on one side only is graded from the surfaced side. The reverse side should usually not be more than one grade poorer.

(2) Variations - The rules generally prescribe the poorest pieces admissible in each grade, but require that the material furnished be representative of the full range of the grade and not mostly of material close to the borderline of the next lower grade. The number of imperfections permitted generally varies with the size of each piece, but the size of each defect is fixed regardless of the size of the piece. Defects may be permitted in rough lumber which is to be dressed, provided the defects will disappear in dressing.

(3) Trimming - Standard lumber must be trimmed to remove splintered ends and spurs. Thin yard lumber must be trimmed both ends with a prescribed tolerance over nominal length.

(4) Heartwood - Requirements for minimum content of heart are prescribed for select, prime, and merchantable structural longleaf timber, but are no longer prescribed for shortleaf lumber or for other grades of longleaf lumber except as optional special requirements. Cypress is available in a clear heart grade that must be all heartwood. Rules for other woods have varying requirements for heartwood for certain grades. Usually heartwood is measured by determining the percentage of girth constituted of heartwood at the point in the length where it is at minimum. Heart fact lumber is free from sapwood on the face side.

(5) Combination Grades - For the dealer's convenience in handling certain stocks, different grades of lumber may be combined. For example, A and B grades may be combined as B and better grade.

(6) Density Rule - The Southern Pine Association has adopted the so-called density rule which provides that dense southern pine shall average, on either one end or the other, not less than six annual rings per inch and, in addition, one-third or more summerwood (the darker, harder portion of each annual ring), measured over a prescribed portion of a radial line from the pith. Lumber that does not meet the requirements of the density rule may be classified as close-grain or medium-grain lumber. Similar rules apply to Douglas fir and redwood.

(7) Stress Rating - The standard dense structural grades of southern pine and structural grades of longleaf pine are each assigned definite unit working stresses in pounds per square inch for fiber stress in bending, tension parallel to the grain, compression across the grain, horizontal shear and compression parallel to the grain. Provision is also made for meeting specification requirements for special working stresses in horizontal shear, and modified rules for grading of such lumber are established. Stress-rated lumber is also available in practically all other kinds of softwood and hardwood commonly used for construction timbers. The maximum slope of the grain with respect to the longitudinal axis is prescribed for each stress grade in such terms as 1 in 12, or 1 in 14.

(8) Moisture Content - The strength and volume of lumber varies greatly with its moisture content. Most grading rules prescribe maximum percentages of moisture for the various grades and thicknesses for both air-dried and kiln-dried lumber, and provide for meeting more restrictive requirements for moisture content when specified.

Sizes and Lengths.

General.--The dimensions of dressed and rough lumber cited are typical under the present standards. There is some consideration being given to reduce the standard dimensions of some dressed sizes. The inspector should check the requirements of the contract to determine the exact dimensions of the lumber materials required for the work.

Dressed sizes.--Dimensions of dressed lumber are always less than the nominal sizes. The grading rules prescribe the minimum actual dimensions in considerable detail. For lumber over 2 inches thick, the thickness and width are 3/8-inch scant for faces under 8 inches and 1/2-inch scant for faces 8 inches and over.

Match workings.--Tongue-and-grooved flooring, shiplapped siding, and other patterned lumber are manufactured to over-all widths slightly less than the actual widths prescribed for dressed sizes. Width and depth of tongues and laps are fixed for the various grades.

Rough dry sizes.--Dimensions of rough lumber, dry, are generally between the nominal sizes and those specified for dressed sizes. For example, the dimensions of lumber over 2 inches thick are 1/4-inch scant for faces under 8 inches and 3/8-inch scant for faces 8 inches and over.

Length provisions.--Boards, strips, dimension, joints, and timbers are furnished in standard lengths of 4 to 20 feet in multiples of 2 feet; flooring, ceiling, and millwork are furnished in standard lengths of 4 to 20 feet in multiples of 1 foot. Longer lengths may be obtained when specified. When random lengths are permitted, an assortment of lengths between 4 and 20 feet may be furnished, but a fair proportion must be over 10 feet.

Preservative Treatment.

Preservative treatment of lumber and timber is essential for durability under various conditions of exposure. Inspection of treated timber will usually be in accordance with applicable instructions of the American Wood-Preservers Association or other requirements as set forth in the specifications.

Delivery and Storage.

Material check.--When timber is delivered to the site of the work for incorporation into a structure, the inspector should make sure that it has been inspected and grade marked as required by the specifications, and that the tally of materials delivered is correct. If it is treated material, the inspector should determine that the reports of treatment are received, that the treatment complies with requirements and that the lumber is properly stamped to identify it with the treatment reports. Timber materials that do not meet specifications should be plainly marked "Reject", and a detail record made in the Job Diary as to description of the material and the reasons for rejection. Timber delivered to the site by the contractor for his own temporary use during construction does not require inspection.

Unloading.--The inspector should check that all timber is unloaded so that it is not damaged in handling and that special care is taken in handling timber treated with creosote or other preservatives to prevent damage to the surface layers.

Storage.--The inspector should require that timber be stored in a well-drained area, that it is clear of the ground, and that it is stacked so that it will maintain its shape and that there is good circulation of air through the pile. In stacking, one end should be raised so that water will drain. Adequate support should be provided so that the lower layers will not be crushed or damaged by the weight of material above them. Kiln-dried timber and finish lumber should always be stored under cover.

Treatment of Cut Surfaces.

All surfaces of materials, cut, planed, or defaced should be painted or brushed with the type of preservative used in the original treatment or as shown in the specifications or on the drawings.

Erection Procedure.

The inspector should make sure that the work is performed to the required standard for workmanship and quality and the methods for erection are safe. All lumber and timber should be accurately cut and framed to a close fit and have even bearing over the entire contact surfaces. Shimming should not be permitted in making joints.

Bolt holes should be drilled to specified size and true in alignment. All in-place bolts should be checked for proper washers and tightness.

Nails and spikes should be driven with care. Bent and otherwise damaged nails do not meet the requirements. All nails should be driven

head flush. Do not allow overdriving which leaves deep hammer marks on the wood surface.

Wood surfaces which require field painting will be prepared and coated as specified. Painting should be permitted only when moisture and temperature conditions are within the limits outlined in the specifications.

Inspector's Check List--Installation Timber Structures.

1. See that all members are of correct dimensions and are cut or formed to exact shape.

2. See that members are properly aligned and fitted together with full bearing and without shims or other adjusting devices except as specifically permitted.

3. Determine that bridging has been installed where specified. Do not permit nailing of lower ends of cross bridging until flooring or decking is in place.

4. Make sure splices over bearing supports are lapped and spiked or bolted.

5. See that bolt holes are properly located and bored to correct alignment. Require proper undersized hole when drive fit is specified.

6. See that all cuts, holes and abraded surfaces made on the job in treated timbers, are re-coated with approved preservatives prior to installation.

7. Be sure all bolts, driftpins, ring connectors, spikes and other hardware are of the specified dimensions, that materials are galvanized, if required, and are properly installed and tightened or driven home without damaging the timber.

8. Determine that the work is properly braced, guyed, or supported at all times to protect against distortion or collapse.

9. Check all timber and hardware for damage before and during erection.

10. Be sure that temporary holding or aligning devices are provided and used as necessary to assure tight, accurate work, that these devices do not injure or mar the finished work, and that they are removed upon completion of erection.

11. See that ample length of threads are provided on bolts to allow for future retightening if the timber shrinks.

12. Check that all bolted connections are tight just prior to acceptance of the work. Drying and seasoning of wood usually results in bolts becoming loose.

13. Make sure all wood surfaces are prepared and painted as specified.

14. Determine that all required material certifications have been received and that all materials meet the specifications.

Asphaltic Concrete Canal Lining

Hot mix asphaltic concrete consists of a combination of aggregates uniformly graded, mixed and coated with asphalt cement. The term "hot mix" results from the requirement that the aggregates be dry and that the cement must be hot to secure the required fluidity for satisfactory mixing, workability, and compaction.

Materials.

The concrete product consists of coarse and fine aggregates including filler (materials passing 200 mesh sieve) which meet specified grading requirements, and asphalt cement.

Representative samples of the aggregates that are proposed for use in the mix should be tested as required by the contract.

The asphalt cement also should be tested for quality, if required, or at any time during construction if there is question as to quality.

All materials should be approved prior to the start of the operations, and additional tests made during the work as required to maintain uniformity.

The Mix.

Responsibility for the design and control of the mix will be governed by the contract specifications. The mix should be designed to best utilize the aggregate sizes available and to meet the specified grading.

The asphalt requirement should be maintained near the upper range determined necessary from preliminary tests to provide a lining of good service life. The total weight of batch should not be designed to exceed the mixer capacity.

The Plant.

Successful production of a uniform product requires that:

1. The aggregates be properly graded.

2. The blending of aggregates and the asphalt cement be uniform.

3. The mix be blended at an even temperature.

Some points to watch at the plant that may cause irregularities and an unsatisfactory mixture:

The cold feed provides that the delivery of aggregates from the stock pile to the drier must be consistent and of uniform gradation. Improper stockpiling, malfunction of the feeders and variable moisture in the aggregates can create adverse operations.

The drier consists of a revolving drum in which the coarse and fine aggregates are dried and heated. The diameter, length and slope of the drier and the turning speed and arrangement of the cups or lifters control the time the aggregates remain in the drier.

Driers are often fired with fuel oil. Incomplete combustion may coat the aggregates with an oily residue which later restricts uniform coating with asphalt. Aggregates should be checked for moisture content and smoke coating as they leave the drier. Improper drying can be detected in a sample by steam or damp spots on the aggregate.

The heat indicating device is important and must operate within the specified range. The sensing element should protrude into the main aggregate stream flow and be so located and insulated from the heat of the burner so that the accuracy of the temperature readings will not be altered.

The dust collector system provides an adequate draft through the drier and also collects and returns a uniform amount of the fine material drawn off by the draft. This unit should be checked to determine that it is properly maintained and adjusted.

The screens separate the aggregates into sizes as they are delivered from the drier into the bins. The fine 1/4-inch screen is generally the controlling factor. When production is maintained in excess of the capacity of the screens, carryover of one size fraction into the next larger fraction can occur. Carryover is usually controlled by specification and should be checked. Screens should be checked for wear holes and breaks.

The bins hold the dry hot screened aggregates. They should be designed for adequate capacity, and must be free of holes to prevent overlap of sizes.

Overflow vents should be provided in each bin to control the level of the material.

The asphalt plant should be checked to determine that the aggregates are accurately proportional and that all materials enter the mixer. All scales should be checked to determine that they meet the requirements for accuracy. A common cause for poor quality in asphalt concrete is incorrect asphalt content. Often this deficiency results from malfunction of the asphalt scale. It is very important that the asphalt scale operates properly and that all moving parts are free from bind or drag.

Most asphalt plants use the pug mill type mixer, which consists of a chamber with two horizontal shafts equipped with a system of mixing paddles. The setting of the paddles and the direction of throw may vary, depending on whether the plant is continuous or a batch type. The mixer should be checked to see that it is not overloaded, which will cause part of the material to float above the paddles, or

underloaded which permits the paddles to rake through the material with little mixing action. The inspector should see that all aggregate is uniformly coated and that there are no dead spots in the mixer.

Transporting Mixed Material.
Asphalt concrete is commonly hauled from the mixing plant to the job in trucks. The truck beds should be tight and clean. When the inside surfaces are lubricated with oil, care must be exercised that an excessive amount is not used. Each truck should be equipped with covers made from heavy canvas or other suitable material to protect the mix from the weather and to retain heat. These units must be properly constructed to dump into spreading machines, windrows or other required disposal locations without delay or waste. Temperature control of the mix may become a problem due to bunching of the trucks, intermittent plant operation, spreading too far in advance, or atmospheric conditions. The inspector should not accept materials for placing that are below the specified temperatures.

Subgrade Preparation.
The subgrade includes the canal sides and bottom upon which the lining will be placed. It should be moist, free from organic and loose material, and compacted to a uniform specified cross section.

Underdrains, when required, should be carefully installed using the materials at the locations specified.

The soil sterilization should consist of the materials and procedures required in the contract. Weeds and other vegetative growth are a potential hazard to asphalt canal linings in many locations. It is important that the inspector check this phase of the installation, noting that the sterilizing materials are well mixed and that the spray equipment has the proper pressure for uniform distribution at a rate that can be absorbed by the soil. Application of the steriliant should be maintained well in advance of placing the lining materials.

Placing and Compacting.
The concrete mixture is commonly placed by slip form or by screeding and rolling.

Slip forms.--Slip forms should be weighted so that they are capable of spreading the mixture to line, grade, and cross section. The slip form should be equipped with a hopper and other accessories which distribute the mixture evenly in front of adjustable strike off and ironing screeds. The screeds should effectively place the mixture without tearing, ridging or gouging, and produce a uniform, even textured surface. The ironing screed, which completes the final finish operation should be heated and weighted as required to produce the specified density and surface texture. The slip form should be equipped with wheels, straight edge runners, or other devices to confine the edges and produce the required thickness and cross section without further treatment.

The hot concrete mixture may be dumped directly into the slip form hopper or it may be dumped into a metal container and rehandled by clam shell bucket or other approved equipment. An important requirement is that the mixture be delivered and placed at the specified temperature. Delays in the placing operation should be avoided.

Screeding and rolling.--The concrete mixture is deposited in place and shaped with screeds. The required density is secured by rolling. This operation should start as soon as the mixture will bear the roller weight without serious displacement. The number of trips and the weight of the rollers should be adequate to achieve the specified density. Initial breakdown rolling with a steel wheeled roller is usually used to set the mix and prevent later displacement. The rolling should be continuous until roller marks are eliminated and the mass has been compacted to a uniform surface and the required density.

Pneumatic rollers may be used for secondary rolling if securing adequate density becomes a problem. Tire pressure and spacing should be checked for proper coverage. Use of pneumatic rollers may have to be delayed until temperature of the mix is reduced to prevent rutting. The surface of the roller wheels should be kept properly moistened. If material tends to stick, soluble oil (mixed about 1 part oil to 50 parts water) added to the roller water may help solve the problem. Steel rollers should always be equipped with scrapers.

Reinforcement.
Steel mesh or other reinforcement may be specified. Since most canal linings are relatively thin, the inspection of the placement, anchorage and the supports for the reinforcement is of vital importance. Reinforcement should be installed well in advance of the placing of the asphaltic concrete to permit inspection. Additional checks should be made during the placing of the mixture to determine that the steel has not been displaced. All reinforcement should be placed as specified and should be free from mud, grease, or other harmful coatings.

Joints.
Transverse joints should be well sealed and bonded as specified. The edge of in-place lining should be cut back to its full depth to expose a fresh surface prior to placing the hot mixture. The contact surface of the in-place concrete may require preheating to insure good bond. All contact surfaces of joints and in-place structures should be coated with a thin coat of hot asphalt cement before placing the concrete mixture.

Areas that cannot be placed and rolled with regular equipment may be placed by hand raking and compacted with hot tampers. Careful inspection is required of these areas to determine that satisfactory bond exists with the machine rolled lining, and that the requirements for density are met.

Tests.
Field tests should be made as specified or directed. These tests may include field density, aggregate sieve analysis, sand equivalent, aggregate moisture and temperature checks.

Inspector's Check List.

1. Determine that aggregates meet sieve and other specified requirements and are properly stockpiled to prevent segregation or contamination.
2. Check that cold feed and drier operate efficiently.
3. Investigate burners for clean efficient combustion of heating fuels.
4. See that the dust collector returns the proper amount of fines to the mix.
5. Check screens for wear and holes.
6. See that bins are not overloaded and that overflow vents and chutes are open.
7. See that scales function properly and are correctly set.
8. See that mixer timing device operates properly.
9. Be sure aggregate particles are uniformly coated at the specified temperature.
10. Check truck beds for excessive oil coatings and adequate covers.
11. See that subgrade is moist, firm and to grade and cross section and that soil has been properly sterilized.
12. See that steel reinforcement is adequately tied and supported.
13. See that the mixture is delivered and spread at the specified temperature.
14. See that the lining material is screeded and compacted in accordance with the specifications.
15. Make certain that joints are properly made and that required coatings are satisfactorily applied.
16. Check thickness of lining and surface for finish tolerance.
17. Collect weight master certificates or loadslips upon delivery of the mix to the job.

18. Do not permit placing operations during or immediately subsequent to rain storms or when subgrade temperatures are near or below freezing.

19. Make density and other tests as required.

20. Record all tests, quantities and Job Diary entries.

Rock Riprap

Purpose.

Rock riprap is composed of a layer of well-sized durable rock fragments. Its purpose is to preserve the shape of a surface, slope, or underlying structure by preventing erosion. A principal use of rock riprap is for upstream slope protection on earth dams. Secondary uses of rock riprap are for the protection of the earthwork at bridge abutments, canal slopes, railroad and highway embankments, levees, culvert headwalls, and stream channels where erosion would otherwise result from turbulence or concentrated flow of water.

Materials.

Rock.--The quality and gradation of rock should be as required in the specifications.

The physical attributes of good rock for riprap are soundness, durability, high specific gravity and resistance to abrasion. In determining quality of rock for riprap, preference is usually given in the following order: (1) igneous rock, (2) massive metamorphic and metamosphosed sedimentary rocks, and (3) well cemented sandstone or limestone rock. The services of a geologist are desirable to identify and aid in determining quality of rock materials.

Frequently, the suitability of a rock source can be evaluated by examination of the same materials that have been subjected to action, similar to the requirements of the contract, for a period of years and have proven through use to be of adequate quality. These evaluations do not eliminate the need for making the material tests required in the contract.

Many failures of rock riprap can be attributed to disintegration of individual stones by alternate freezing and thawing of water absorbed in the pores, cavities or crevices of the material. Temperature variations contribute to a type of rock weathering known as spalling. Other causes of weathering are alternate wetting and drying and the dissolution of water soluble substances occurring within the rock. Rock riprap may also fail from poor gradation, undesirable shape of the fragments, low specific gravity or unstable subgrade or foundation material.

Angular rock which has a low absorption rate and high specific gravity is preferred because of its ability to resist weathering and movement. While it is desirable that the individual stones be impervious, the composite layer of riprap should be pervious. Excessive fines which fill the voids between the rock particles should be avoided to prevent water pressures from building up in the soils which support the rock protection.

When testing is required in the specifications or determined necessary by the engineer, samples should be taken well in advance of installation so that they can be submitted to a suitable laboratory for the

required tests. Often the proposed rock source is used by others, such as state highways, and they have up-to-date test data. If available, this test information should be evaluated for adequacy in lieu of part or all of the specified tests.

Rock from untested sources or rock removed from required excavations on the job should be tested as required in the specifications.

Tests for quality will not be required when the source of rock is specified in the contract, since an evaluation of the material was made at the time of the design.

Only a limited amount of testing can be performed by the engineering force on the job. Bulk specific gravity (saturated surface dry) of the rock can be determined as outlined in Test No. C-11. Tests for compliance with the gradation requirements should be made at the job site. This is a difficult operation and the final determinations of compliance has to be resolved with judgment when evaluating the results of accepted or specified methods.

The size gradation is usually expressed in terms of diameter, passing a given size square opening, or by weight.

One method that may be used to check compliance is to have a representative load of known weight delivered to the job. The individual pieces of rock should be examined visually and measured to determine that the smallest dimension is not less than one-third of the largest dimension and that the minimum diameter or size of the fragments is in the specified range. Sufficient measurements will be necessary to separate the entire load into the various size groups.

When it is required that a certain percent falls within a specified weight range, it will be necessary to measure each stone and compute its volume and weight. Volume can be converted to weight by using the actual specific gravity of the rock or, if not known, an assumed value may be used. For hard dense rock, a specific gravity of 2.6 is common. For other kinds of rock, variations in the range of 2.3 to 2.8 may apply, depending on the characteristics of the material. A field evaluation is illustrated by the following example:

$$\begin{aligned}
\text{Specific Gravity} &= 2.6 \\
\text{1 cu. ft. of rock} &= 62.5 \times 2.6 = 162.5 \text{ lbs.} \\
\text{1 cu. in. of rock} &= \frac{162.5}{1728} = 0.94 \text{ lbs.}
\end{aligned}$$

Measure each piece of rock in the sample load and separate into piles by size. Results may be tabulated as follows:

(1) No. Pieces	(2) Size (Inches)	(3) Volume Each -- Cu. In.	(4) Weight-Each (3) x .094	(5) Total Weight (4) x (1)
10	12" x 12" x 15"	2160	203	2030
6	15" x 18" x 12"	3240	304	1824
15	12" x 10" x 8"	960	90	1350
12	12" x 8" x 15"	1440	135	1620
60	6" x 8" x 8"	344	32	1920
100	6" x 6" x 4"	144	14	1400
150	4" x 4" x 3"	48	5	750
			TOTAL WEIGHT --	10894 lbs.

Size Range 200 - 350 lbs. = 3854 = 35.5%
Size Range 75 - 200 lbs. = 2970 = 26.8%
Size Range 75 Under = 4070 = 37.5%

The weight of the load as determined by the above procedure should be checked with the delivery weight of the sample to be certain there is no wide discrepancy in the calculations.

If a higher degree of accuracy is required, the various sizes may be weighed.

Filter Material.

Filter materials used as bedding for the rock riprap should be composed of tough, hard, durable, well-graded material reasonably free from thin, flat and elongated aggregates. The filter material should not contain organic matter or soft friable particles which will disintegrate. The material may be composed of sand, sand and gravel mixture, gravel or crushed stone which is graded within the limits shown on the contract drawings or in the specifications.

Types.

Equipment placed.--Experience has shown that equipment may be used successfully in placing rock riprap. The rough surface produced reduces wave travel on the embankment slope and where heavy protective cover is required, it is often cheaper to construct than other types

since little or no hand labor is required. However, hand placing may be specified for areas adjacent to structures or other critical locations.

Placement of rock by means of a bulldozer with a rock rake attachment is sometimes employed. Proper sorting of the material as it is moved into position on the area to be protected is an important consideration in evaluating the effectiveness of this method.

A power crane equipped with a clamshell bucket or a dump type skip has proven to be very satisfactory for placing rock riprap. This equipment, properly operated, will maintain gradation and thickness with a minimum amount of reworking of the material.

Hand-placed.--Hand-placed riprap is limited to smaller structures which must be protected from flowing water, stream erosion, or moderate wave action. This method of placement requires smaller rock, usually quite uniform in size, placed systematically by hand methods. Rock spalls and small fragments are sledged in place to bind the surface and fill spaces between the larger fragments. The largest pieces used are usually smaller than those required for machine placed riprap. The principal disadvantage of hand-placed riprap is the weakness of its single-course construction. Any displacement which occurs in the protective course will expose the underlying material to erosion.

Installation.

Foundation preparation.--The surfaces on which the filter blanket or rock riprap is to be placed should be trimmed and graded to conform to the lines or sections shown on the contract drawings. Surfaces which are below grade should be brought to grade by filling with well compacted material. When approved, the contractor may elect to place extra blanket or riprap material in lieu of compacted earth.

Filter blanket.--When shown on the drawings, a filter blanket will be placed underneath the rock riprap. The materials used in the blanket should be checked for gradation and quality. The filter materials should be spread uniformly on the prepared surface to the depth and lines indicated on the drawings or as established in the field. Compaction of the filter blanket should be as specified and finished to a reasonably smooth, even surface. Operations in connection with the placement of the riprap material require care to prevent displacement of the filter materials. To avoid displacement, where large surface areas are involved, it may be desirable to restrict placing of filter material to narrow strips in advance of placement of the rock riprap.

Placing.--Machine placed riprap should be placed by equipment on the surfaces and to the depths indicated on the drawings or as staked on the ground. The riprap should be placed to the full course thickness in one operation and in such manner as to avoid serious displacement of the underlying materials. The riprap should be delivered and spread so that the mass of stones in place are reasonably well graded, with the larger rocks uniformly distributed and the smaller rocks and spalls filling the voids between the larger rocks. Some hand-placing may be

required to insure that no large void spaces exist. The exposed surfaces of the in-place material should be reworked and dressed as required to provide a finish that is pleasing in appearance and within the tolerance limits specified.

When hand-placed riprap is called for on the drawings, the rock should be placed by hand on the surfaces and to the depths indicated. The riprap should be placed in such manner that adjacent stones are in close contact and, in general, have the greatest dimension across the slope. Spaces between the larger stones should be filled with the smaller stones of acceptable size. Small stones should not be grouped to fill the space which would normally be taken by a larger stone. Flat slab rocks are undesirable. If used they should be placed on edge.

Inspector's Check List.

1. Determine that the surfaces to be protected are complete to the lines and grades shown on the drawings, and are free of unstable material.

2. Make sure that rock and filter materials meet the quality and gradation requirements specified.

3. See that filter blanket is uniformly placed at the location and to the thickness required.

4. Make sure that rock is acceptably graded when delivered to the job. Do not permit soil fines to become intermixed with the riprap during placing operations.

5. Determine that rock is placed to the required thickness. Make sure the method of placement is adequate to prevent segregation of rock sizes.

6. See that the continuity of the filter blanket is not broken while placing riprap.

7. Check the riprap after placing to determine that rock sizes are well distributed and that minimum sizes fill the voids between the large rock.

8. See that the riprap is placed within the tolerances specified.

9. Make sure that rock is hand placed at the specified locations.

10. See that weight slips are delivered with each load.

11. See that backfill or other required earthwork is completed as shown on the drawings.

12. Record all tests, quantities and Job Diary entries.

Grouted Rock Riprap

Grouted rock riprap protection is often utilized where large rock are not economically available in adequate quantities, and where protection of a heavy service type is required. This construction procedure provides a heavy mass of smaller stones bound together by a mortar grout. Grouted rock riprap is adapted to slope and invert protection for variable flow conditions including high velocities. It is not uncommon for the design to require that oversize stone be placed in a variable pattern to produce a rough surface for the reduction of velocity in the protected area.

Materials.

Stone.--All stone should be sound, dense and durable rock free from any adherent coating, and which meets all the test requirements of the specifications. The shape and gradation are important for satisfactory construction. Well-graded angular rock are preferred. An excess of maximum size rock results in extra voids, while an excess of minimum size may result in stones being placed in layers to meet the required thickness.

Concrete grout.--The grout is composed of cement, concrete sand, coarse aggregate (usually limited to 3/4" maximum) and water mixed in the proportions specified or as required by the engineer. The grout should have adequate slump to permit gravity flow into the voids between the rock fragments with the minimum amount of placing effort. Conversely, the mortar also must have adequate stability to remain in place without excessive movement when placed on slopes. The use of air entraining admixtures are desirable to improve workability and reduce labor in placement.

Subgrade.

Adequate foundation is essential for this type of protection. The sections are commonly placed continuously without joints or other provisions for uneven settlement. The area to be treated should be graded to the cross-section shown on the drawings and carefully inspected for wet or soft areas prior to placing the materials.

Extra precaution is required to see that the foundation excavation is into stable material and the beginning and end of the section are adequately excavated to prevent undermining of the grouted section.

Bedding or drainage material, when specified should be checked for quality and gradation and to the required thickness. Material for weep holes or other required drainage features should be inspected for size and location of installation.

Placement.

Rock which meets the requirements may be placed with equipment, utilizing hand labor only as necessary to produce the gradation, thickness and surface specified. The rock should be placed relatively close together in a manner that will not disturb the bedding material. The larger stone should be distributed throughout the rock mass. The

stone should be arranged to eliminate large pockets, and the voids partially filled with the necessary spalls or smaller rock. Stone should not be decked one above the other to meet the required thickness. Prior to placing grout, the rock should be flushed with water using pressure as required to expose a clean surface.

The rock should be kept wet immediately ahead of the placing of the grout.

The grout should be properly proportioned and mixed to the required slump.

The grout may be placed with buckets, chutes, pipes or other conveyance so long as the materials are not permitted to segregate. A strip about ten feet wide should be covered at a time, and placing should be continuous for the day's operation. On slopes, the work should start at the bottom and proceed to the top. The grout, if discharged in large quantities, should be landed on a platform to prevent movement of the inplace riprap.

The primary objective in placing the grout is to see that it penetrates to the full thickness of the riprap and completely fills the voids. Small vibrators and bars aid in getting penetration of the grout. Shovels and stiff bristle push brooms are practical for moving excess mortar up slope and final clean up of the surface area. It is desirable to expose the surface of the larger rock, since thin coatings of mortar tend to weather and spall. On steep slopes it may be necessary to place the grout in two separate courses to prevent excessive down slope movement. The final operation should be brooming up slope to eliminate runs and to make sure all voids are filled.

Curing and Protection.

The same curing requirements as specified for concrete, apply to grouted rock.

If water is used, fog nozzles or wet absorptive cover should be applied as soon as the concrete has taken initial set, and kept wet for the specified curing period.

When curing compounds are used, they should be applied at the specified rate soon after final placement of the mortar.

The surface of freshly placed mortar should be protected from rain or running water. The riprap should be protected from mechanical injury or loadings during the curing period.

Travel over the surface of fresh grout by workmen should be limited, for the first 24 hours, to the extent required to complete the work.

Grout should not be applied when the subgrade is frozen or when the air temperature is near or below freezing. Adequate protection should be provided to maintain the temperature of the inplace riprap for the duration of the curing period.

Tests.

No formal tests of the finished product are required. Tests for the quality of the rock and the ingredients for the grout should be made as required to ensure that the materials are satisfactory.

Inspector's Check List.

1. Determine that the subgrade is to line and cross section. See that low areas are filled with compacted earth or additional bedding material.

2. Check subgrade for wet or unstable areas and provide drainage as required. Remove all water from site so work can be placed in the dry.

3. Make sure excavation at either end of the protected area is adequate for cut-off protection.

4. Determine that the rock and grout materials meet the requirements for quality.

5. See that the rock is graded as specified. Be careful that excess amount of minimum size rock is not used.

6. See that rock is placed to required thickness, and is not placed in layers.

7. See that oversize rock protrudes above finish grade as specified.

8. Check the mix and slump of the grout. Make sure that the consistency is satisfactory for placement.

9. Do not permit dumping grout at high discharge rate unless splash plate is used.

10. See that grout is made to penetrate full thickness of rock layers and that it is not permitted to flow to the extent that segregation takes place.

11. Insist that grout be placed working from bottom to top, on steep slopes.

12. See that voids are filled, runs removed and rock surfaces brushed to remove excess mortar.

13. See that weep holes are in proper position and are clear of obstructions.

14. See that the finished riprap is cured as specified.

15. Make sure riprap is protected from loads or mechanical damage. Limit travel over surface by workmen for first 24 hours.

16. See that fresh mortar is protected from rain or running water.

17. Do not permit placing grout during freezing temperature. See that grouted rock is protected from freezing for the specified curing period.

18. Make sure batch tickets are collected for each load of grout delivered to the site.

19. Keep detail record of amounts of grout wasted on the job.

20. Make material tests as directed.

21. Record all tests, quantities, and Job Diary entries.

Sacked Concrete Riprap

Sacked concrete is a revetment type of protection, consisting of portland cement concrete placed in cloth or composition sacks, and laid in a pattern similar to rock masonry.

To attain the desired success for this type of construction, it is very important that the foundation be free from settlement and that the ends of the constructed section be adequately tied into undisturbed natural features that will resist erosion. Sacked concrete must be considered as an inflexible type structure. Certain weaknesses are inherent in its construction, such as, for steep slopes, the ability to resist pressures associated with retaining wall construction and on flatter slopes failure may occur due to lack of bond between adjacent rows of the sacked concrete.

Sacked concrete may be used to protect stream banks or for control of erosion adjacent to concrete structures or other appurtenances.

The foundation and sloped areas should be graded as shown on the drawings. It is important that the subgrade be inspected to determine that it is firm and meets the requirements of the contract. Drainage materials or appurtenances should be installed as required.

Materials.

Concrete.--A dry mix of portland cement, sand and coarse aggregate may be specified. In this case the water of hydration is provided by atmospheric moisture.

Strength tests are not normally required since relatively low strength (approximately 2,000 lbs./sq.in.) is usually adequate for this kind of construction. The control of the slump is important in order to facilitate proper installation. Concrete should be mixed on the wet side and is often specified at about a 5 inch slump.

Sacks.--The sacks may be burlap or other specified woven material of adequate capacity and strength. Burlap grain type sacks are desirable due to size (about 20" x 36" measured between seams) and the open weave of the material.

Placement.

Special precaution should be taken to see that the base courses are placed according to the drawings and the specifications.

If a double base course is required the first row is usually placed as a double row of "stretchers" (length of sack parallel to slope).

The second base course is placed as "headers" (sacks placed at right angles to stretcher course).

The next row and succeeding rows are usually placed as "stretcher" courses, and they should be laid so that joints between sacks in succeeding courses are staggered.

The sacks should be filled with fresh concrete, about 1.0 cu. ft. per sack, making sure that there is adequate length of sack to fold or tie as required.

The sacks should be placed immediately after filling with concrete. Sacks laid as "stretchers" should be placed so that the folded ends are not adjacent to each other. Sacks laid as "headers" should be placed with the folded end toward the subgrade or bank.

After placing, each sack should be lightly trampled to cause them to conform with the subgrade and the adjacent in-place sacked material, and also to extrude some of the mortar from the mixture. The additional bond developed between courses which result from the extrudation of the mortar is of importance.

All dirt or other debris should be carefully removed from the top of the in-place course before placing sacks for the next course.

<u>Curing and Protection.</u>
The strength and durability of the sacked concrete revetment can be improved by proper curing. Due to the characteristics of the materials used in construction, the water curing method is preferred.

To maintain satisfactory moisture conditions, the surface of the revetment should be sprinkled lightly at least every 2 hours during the daytime, or the surface completely covered with earth or other absorptive materials that are kept wet for the specified curing period.

Curing should start as soon as the concrete has set.

Restrictions and protection required for sacked concrete placed during cold weather should be as specified for regular portland cement concrete construction.

<u>Tests.</u>
No formal tests are required for quality of the in-place revetment.

Approval of the quality of the cement and aggregates used in the manufacture of the concrete may be necessary and tests of the materials should be made as required.

<u>Inspection Check List.</u>

1. Determine that excavations for foundation and bank subgrade are to the lines and grades specified and that the foundation materials have adequate bearing strength.

2. See that concrete and sack materials meet the specifications.

3. See that adequate equipment and labor are available to maintain continuous operation during placement of the revetment. Do not permit use of partially set or retempered concrete.

4. See that the site is dewatered so that materials can be placed in the dry.

5. Make sure that sacks are filled and placed as specified.

6. See that weeps or other required drainage features are installed.

7. Observe that adequate mortar is expelled through the mesh of the sacks to give proper bond.

8. Make sure that the surface of the in-place sacks are free from dirt or other debris before placing next course.

9. Require adequate protection at the beginning and termination of the riprap section to prevent erosion damage to the structure.

10. See that the revetment is cured as specified.

11. Make sure that the work is adequately protected during cold weather.

12. Make material tests as required.

13. Record all tests, quantities, and Job Diary entries.

Soil-Cement Construction

Soil-cement is a mixture of pulverized soil and measured amounts of portland cement and water compacted to a high density. When portland cement and water are mixed with a soil, the cement reduces the plasticity of the soil, decreases its water holding and volume change capacities, and increases its bearing value and shearing strength.

Soil cement mixtures may be specified for use on various types of Service work such as canal linings, reservoir linings, facings for dams, dikes or berms, improvement of granular subgrades or base courses and for road surfacing.

Types of Soil-Cement.

Three general types of soil-cement mixtures may be specified:

(1) Compacted soil-cement.

(2) Cement-modified soil.

(3) Plastic soil-cement.

Compacted Soil-Cement.--Commonly referred to as soil-cement, contains sufficient cement to harden the soil, and an adequate amount of water for compaction and the hydration of the cement.

Cement-modified soil.--Is an unhardened or semi-hardened mixture of soil and cement. In cement-modified soil, the cement requirement is less than for soil-cement, and only enough is used to change the physical properties of the soil to the desired degree.

Plastic soil-cement.--Contains sufficient water to produce a consistency similar to plastering mortar, as compared to soil-cement that contains only adequate moisture to permit compaction and hydration of the cement. Plastic soil-cement is used primarily for irregular or confined areas where it is difficult to place and compact with heavy equipment.

Materials.

The three basic materials required for soil-cement construction are, soil, portland cement and water.

Soil.--The bulk of the soil-cement consists of soil which is either in place or obtained within a short haul.

Practically all soil texture combinations can be used including combinations of gravel, sand, silt and clay.

Sandy and gravelly soils with about 10-35 percent silt and clay generally require the minimum amount of cement.

Sandy soils deficient in fines may be used, however, the design will usually require a higher percent of cement.

Cement.--Any type of portland cement meeting standard reference specifications may be used. Type I cement is commonly specified because of its availability.

Water.--The water should be free from injurious amounts of alkalies, acids and organic matter.

The Mixture.

Cement content.--Proper cement content is the first requisite for soil-cement construction. Before construction starts, the soil on the project that is proposed for use should be sampled and tested in the laboratory and a satisfactory mix designed for the work.

Water content.--Water performs two functions in a soil - cement mixture. It lubricates the mass to facilitate compaction, and it hydrates the cement. The amount of water to be added will depend on the optimum moisture content specified for the mixture and the amount of moisture present in the untreated soil.

It is highly important that the total moisture content be maintained at the specified amount.

Installation.

Initial preparation.--Before other construction operations are started, the area to be treated should be shaped to conform to the lines, grades and typical cross sections shown in the drawings. Unsuitable soil should be removed and replaced with acceptable material, and additional soil placed as required. The subgrade should be firm and capable of supporting the construction equipment, and the design loads after treatment.

Scarifying and pulverizing.--For jobs that permit processing the soil in place, the first construction operation consists of scarifying the surface to the specified depth. The effective depth should be checked immediately after starting equipment, and adjustments made until the depth is definitely under control. Equipment should be routed so that it operates over an undisturbed surface to maintain uniformity of depth.

After the surface is adequately loosened, the material should be worked by equipment to pulverize the material to the gradation specified. Usually this will require that 100 percent of the material passes the 1 inch sieve and 75 to 80 percent passes the No. 4 sieve, exclusive of gravel or stone retained on the sieves.

Many combinations of sand, silt and clay occur in nature and each soil has its own pulverizing charactistics. The moisture content of the soil often has a major effect on the rate of breakdown and the equipment required. When the heavier soils have moisture contents near the

shrinkage limit, they may be very hard and difficult to break down, and when the moisture content is near the plastic limit they tend to pack together. The friable soils generally pulverize readily when the moisture content is near the plastic limit. Equipment such as rotary speed mixers, harrows, offset disks, rollers and mold board plows may be required to pulverize the soil.

Soil-cement for steep slopes or for restricted areas may be mixed in a central plant or in mixers at the site. The material should be conveyed immediately from the mixer to its final position.

Spreading cement.--Immediately prior to adding cement, the pulverized surface should be checked for cross section and grade and reshaped as required.

Cement may be added mechanically by spreaders or by accurately dumping bag cement to a predetermined pattern. All operations will be governed by the requirements of the specifications. Adequate control of the cement is essential. Mixing should start immediately after adding the cement.

Some of the same units used to scarify and pulverize the soil material are often found to be satisfactory for mixing the soil and cement. For large jobs, a traveling mixing machine may be used that adds the cement and water and mixes and processes the scarified or windrowed soil in place, all in one operation. A careful check of the amount of cement added and the uniformity and depth of the soil cement mixture is necessary at all times.

Water Spreading and Mixing.--Usually it is possible to mix cement with soil without forming cement balls if the moisture does not exceed the optimum moisture specified for the soil-cement mixture by more than two percentage points. It is desirable to have the raw soil about two percentage points below optimum for good mixing.

Moisture tests should be made during the mixing process so that the final water requirements will be known. Water should be added as required and final mixing started as soon as possible after the cement has been incorporated with the soil.

The moisture content of the soil-cement is critical and should be at least optimum and not more than about two points above prior to compaction.

Soil-cement mixtures should be compacted immediately after mixing, and should not remain undisturbed for more than 30 minutes.

Compaction.--After a uniform mixture of soil, cement and water has been obtained, the area should be scarified to give a loose mass which can be compacted uniformly. Pneumatic, sheepsfoot or steel wheeled rollers are commonly used to attain the required compaction, however, other types of equipment may be specified. The equipment should be routed to provide uniform coverage.

The density of the compacted material should be determined at several locations at the start of the work. Comparison of these densities with the maximum density as determined by the field moisture density test will indicate need for a change in compaction procedures and equipment.

Curing.--Compacted soil-cement contains sufficient moisture for hydration of the cement. It is important that some type of cover or seal as required in the contract be placed over the finish surface soon after completion to retain the moisture. A light application of bituminous material is commonly specified, but other materials, such as canvas, burlap, waterproof paper, moist straw, or dirt are often used.

It is not uncommon for shrinkage cracks to form after construction. Cracking is a natural characteristic of soil-cement and does not detract from the performance of the material as a base course. These cracks usually do not penetrate through the full thickness of the layer on a frequent pattern. However, numerous surface cracks may be observed. Additional surface treatment may be specified for locations requiring a watertight lining.

<u>Cement-Modified Soils.</u>
In cement-modified soil, only enough cement is used to change the physical properties of the soil to the desired degree.

Construction procedures are similar to those used for soil-cement, although not as exacting. The cement and water should be uniformly incorporated and the mixture compacted. Compaction operations should be the same day the material is placed to obtain maximum benefit. Curing is often omitted for this material.

<u>Plastic Soil-Cement.</u>
Plastic soil-cement contains more water and is commonly mixed in a concrete mixer. Since the consistency is similar to concrete, the placing, vibrating, finishing and curing is carried out with about the same requirements as for concrete.

<u>Testing.</u>
Soil-cement construction requires tests similar in procedure and equipment to those required for compacted embankments.

The moisture-density test (AASHO T-143-45 or ASTM D-558-44) is made on the moist mixed soil-cement at the time of compaction to determine the "optimum moisture and the maximum density requirements."

Tests of the completed work include a density test (sand cone or water balloon equipment) and a depth test.

Additional field checks, such as adequate pulverization, uniformity of cement spread, and uniformity of mix and depth of treatment are essential to securing a satisfactory job.

The test procedures and the required number of tests will be in accordance with the specifications and instructions issued by the State Conservation Engineer.

Inspector's Check List.

1. See that area to be treated is graded within the specified tolerance for line, grade and cross section prior to start of work.

2. Determine that soils are similar to samples used in the design.

3. Observe subgrade for soft spots and uniformity of texture of material. See that unsatisfactory materials are replaced.

4. Measure depth and uniformity of scarification.

5. Make tests to determine soil materials are pulverized as specified.

6. See that the rate of cement application is uniform and as specified.

7. Determine that soil and cement are thoroughly mixed to plan depth and section, do not permit depth to exceed the requirement.

8. Do not permit application of cement over more area than can be mixed and compacted in continuous sequence.

9. Make sure cement is not added to soil containing an excess amount of moisture.

10. Test soil-cement to determine that moisture is as specified prior to compacting.

11. Do not permit operations if soil is frozen or temperatures below freezing.

12. Make sure adequate facilities are available to protect uncompacted soil-cement from heavy rain.

13. Make in-place density tests to determine adequacy of compaction.

14. Check thickness of compacted layer, and surface finish for uniformity and grade.

15. See that completed surface is cured as specified.

16. Make sure soil-cement is protected from freezing for the curing period.

17. Record all tests, quantities, and Job Diary entries.

Water Control Gates and Valves

Types.

Flap gates.--Flap gates are used largely to prevent backwater overflow to protected areas. They are designed to open freely to allow water passage when pressure is applied on the gate. They are manufactured of lumber, cast iron, cast steel or welded steel plates as required to meet the designed heads. Seating surfaces should be either cast iron or bronze mounted and ground to a close fit.

Slide gates.--Slide gates consist of a control assembly, seat, and a slide with a rectangular or circular opening. The slides are made of lumber, cast iron or welded steel plates, with necessary reinforcing ribs designed to withstand the specified maximum hydraulic head. The seat and slide are supplied with facings of either cast iron or bronze securely attached and accurately machined and fitted. Guides are made of structural steel or cast iron with provisions made in the slide and guides, by means of wedges or other approved devices, to insure the practical watertight seating of the gate when closed. Gates are made to attach directly to a wall, flat back type, or they may be attached to a thimble, flange, and/or spigot. Threaded stem, cable or chain hoists are provided for raising the slide gate.

Radial gates.--Radial gates consist of a structural steel framework with a metal skin plate securely riveted to the frame and designed to withstand the maximum head shown on the drawings. They are provided with bearing pins and bearing blocks designed for embedment in the concrete. Flexible rubber seals are provided for the bottom and for the edges in contact with the sidewalls and floor slab. Each gate is supplied with a hoist for raising and lowering the gate.

Valves.--The types, sizes, working pressure and end connections of valves will normally be shown on the drawings or the requirements outlined in the specifications.

Inspection.

Material check.--The inspector should carefully inspect all water control gates and valves when they arrive on the job. All parts should be checked for defects in the manufacturing process, for possible damage in transit, for conformity with the specifications, and for compatibility of assemblies and accessory parts.

An entry should be made in the Job Diary of any materials delivered that are defective or damaged. An entry should also be made for materials that are rejected and the reason for rejection.

Storage.--All gate and valve assemblies should be stored in a suitable place to prevent rust, corrosion or any other damaging effect to the equipment or any part thereof.

Installation.
Valves, gates and appurtenances should be carefully installed in conformance with the requirements of the drawings and the manufacturer's instructions.

Gates and valves to be water tight when working under medium to high heads require careful machining and adjustment at the factory. These assemblies should not be dismantled on the job. Extra care is required in mounting gate seat castings to prevent warping or distortion. Anchor bolts should be carefully positioned and rigidly held in place. Concrete surfaces used for bearing or support should be smooth and uniform. All anchor bolts should be tightened to a uniform tension, using caution that metal parts retain correct fit and alignment.

After installation, all valves, gates and appurtenances should be tested by opening and closing through the full range of operation. Attention should be given to the operation of each detail part of the assembly to make sure all parts are properly aligned and anchored, and that they function without unnecessary strain or distortion. The contractor should make adjustments as required to provide a water-tight, smooth-working installation.

Inspector's Check List.

1. Make sure valves, gates and appurtenances meet the requirements of the contract. See that templates and instructions for installation are furnished by the manufacturer as required.

2. See that materials are stored and handled so that they are not damaged on the job.

3. Do not permit contractor to disassemble valves or gates furnished for control of high heads without approval of the engineer.

4. Make sure anchor bolts or other embedded items are properly aligned and anchored in the forms prior to placing concrete.

5. See that metal embedded in concrete is free of paint, grease, oils, flaky rust or other coatings that might prevent bond.

6. Check that required recesses are formed to specified dimensions.

7. See that gate assemblies are held in true position and alignment when grouted seats are installed.

8. Make sure that concrete surfaces in contact with gate seating rings are smooth and uniform. Check that gaskets or grout are installed as specified.

9. See that hoists, stems, stem guides and other appurtenances are placed in correct alignment.

10. See that appurtenances are properly installed with anchor bolts and washers or other fasteners or assemblies, as specified.

11. Make sure flap gates are installed with seating face in a vertical plane, or with bottom projecting slightly forward.

12. Test all valve and gate installations for watertightness, and smooth performance throughout the operating range.

13. Make sure that gate assemblies are cleaned and lubricated as specified.

14. See that protective coatings meet the requirements and are applied as specified. Make sure that damaged shop coatings are retouched before applying final field coatings.

15. Check that certifications for all items are furnished prior to installation.

16. Record all quantities and Job Diary entries.

Fences and Fence Construction

Types.
Barbed wire.--This type of fence usually consists of two or more strands of wire and is used to contain large domestic animals.

Woven wire.--This type of fence consists of woven wire next to the ground and may have one or more strands of barbed wire. This type is commonly used to contain smaller domestic animals.

Chain link.--This type of fence consists of heavy, close-spaced, woven wire fabric which will normally be utilized for urban, industrial, institutional, or residential property.

Materials.
Wire.--The wire should be of the type, gauge, class, spacing, and coating as shown on the contract drawings or in the specifications.

Wood posts and braces.--Wood posts and braces should comply with the specifications in all respects, including species of wood, dimensions, soundness, straightness, and treatment.

Steel posts and braces.--Steel posts and braces should be of the type, weight and dimensions shown on the contract drawings or in the specifications. The posts should be corrugated or embossed for attaching the wire in a manner that will not damage the post or fencing material.

The surface coating should be as specified. All steel posts and braces, except galvanized materials, should be painted. Areas damaged during construction should be spot coated with paint of the same color. Galvanized posts and bracing should be treated in accordance with the specifications.

All posts, braces and gate frames for chain link fencing should be standard galvanized welded or seamless steel pipe. Post caps should be heavily galvanized malleable iron, of the drive-fit type, unless otherwise shown on the drawings.

Concrete posts.--Concrete posts should be of the dimensions and specifications shown on the drawings.

Gates.--Gates may be either a manufactured type or fabricated on the job. The drawings and specifications will specify the materials to be used, structural details and dimensions.

Delivery and Storage.
Material check.--As the fencing materials are delivered to the job, the inspector should check to see that they meet the specifications in all respects. Certifications, as required, should be furnished for all materials.

Storage.--When fencing materials are received on the site, they should be stored in a well-drained place and the wire and other metal material supported so it will not come in contact with the ground.

Construction.

Setting posts.--All brace, end, corner, and gate posts should be set vertically in holes spaced at the interval and excavated to the minimum depth and size specified in the contract. After the gate and corner posts are set in place, the hole should be backfilled as required.

All line and brace posts should be set vertically in holes to the depth shown on the drawings, except that steel posts may be driven. All posts should be kept in accurate alignment. All line posts and brace posts, except those set in concrete, should be backfilled with suitable soil material in layers, as specified, and each layer thoroughly tamped.

It is important that corner or pull post assemblies are installed at angles of deflection in alignment, both horizontal and vertical, as required.

Stretching and fastening the wire.--The wire should be stretched between each corner and between the gate posts, adjacent corners, or pull post assemblies. Wire should not be stretched around a corner post. When crossing a hill or valley, care should be exercised that the wire is not stretched too tightly. The tension in woven wire should be controlled so the "tension bends" in the horizontal strands are not eliminated. Reduce tension in all fences installed in extremely hot weather if large variations in temperature prevail in the area. When splicing is necessary, the Western Union splice should be used. The splice should be formed by making at least 8 complete wraps with each end of the wire. The wraps should be tight and closely spaced. Wire should be cut and wrapped at each corner or gate post. The wire should be fastened to the posts in the manner shown on the drawings. Wire staples should be driven diagonally with the grain, angled against the direction of pull, and should not be driven tight against the wire on line posts.

Chain link fencing should be fastened to the posts and the top and bottom edges should be fastened to the horizontal tension wires. The tension wires should be stretched taut and turn buckles should be installed at the frequency specified. Excavations should be made as required to install the bottom tension wire on a uniform grade between posts. The fabric should be fastened to end, corner, and gate posts with stretcher bars and with stretcher bar bands, usually spaced at about 12-inch intervals. The fencing material should be fastened to the line posts and to the tension wires as outlined in the contract.

Gate installation.--The gates should be installed after the fence wire is in place to eliminate the possibility of the gate being pulled out of alignment. Gates should be properly hung so they will open and close easily.

<u>Inspector's Check List</u>.

1. See that wood posts are of the species, size and length specified. Be sure they are straight, peeled and treated as required.

2. See that metal posts are of the shape, size and weight specified, and that surface coatings meet the requirements.

3. See that fencing including fasteners conform to the requirements of the contract.

4. Make sure all metal material is stored off the ground if immediate use is not anticipated.

5. See that the location is adequately staked, including locations for corners, pull posts and gate openings.

6. See that post holes are spaced and to the dimensions shown on the drawings.

7. Make sure posts are set vertical, are properly backfilled with the required materials and are in correct alignment.

8. See that concrete used for post encasement meets the requirements and is properly placed and crowned at ground surface.

9. If driven posts are damaged in the process of installation, they should be replaced.

10. See that braces, tension wires and rods used in corner, gate, and pull post assemblies are properly installed. Tension wires and rods should be taut.

11. Make sure concrete footings and encasements are properly cured prior to use of post assemblies for stretching fence material.

12. See that fence is placed on the side of the post as specified.

13. See that all fencing is stretched taut, making proper allowance for temperature and changes in vertical alignment. Do not stretch woven wire so "tension bends" in horizontal strands are eliminated.

14. Make sure fencing is anchored to posts and tension wires as required. Watch for splits in wood posts caused by improper stapling.

15. See that fencing is not stretched around gate or corner posts. Check that each wire is cut and wrapped around the post and the end anchored by wrapping to form a positive anchor.

16. Be sure fence is properly constructed across depressions or gullies. Check post length, dead weights and anchors.

17. Make sure wire is spliced by the specified method, and that splice ends are properly wrapped.

18. See that damaged surface coatings on metal posts and bracing is spot coated with acceptable material.

19. Make sure that gates are properly assembled and attached. Check hinge bolts and latch assemblies.

20. Determine that all required certifications have been received prior to installation of fencing materials.

21. Record all quantities and Job Diary entries.

Piles and Pile Driving

General.

A pile is a structural member and is generally used to support a designed load. Strictly speaking, piles may be classed as bearing and sheet piles. The three types of materials commonly used are wood, concrete, and steel. Various types of bearing piles are available under trade names, many of which are "composite" piles combining concrete and steel, either installed as a precast or cast-in-place product.

Types of Piles.

Bearing Piles.--Bearing piles transmit and distribute vertical loads into the ground in one of three ways.

(1) Skin Friction - Skin friction is the friction between the sides of a pile and the soil into which the pile is driven. Skin friction provides vertical support. The base of the pile does not rest on a hard surface.

(2) End Bearing - When the base of a pile bears on rock or other hard subsurface, vertical support may be obtained entirely from point resistance and the pile acts as a column. The earth around the sides of the pile furnishes lateral support only.

(3) Combination of Skin Friction and Point Resistance - When a pile is driven through soil to a stiff resisting layer, skin friction and point resistance are combined and the load-carrying capacity is derived partly from each.

Tension piles.--Tension piles resist upward forces like a vertical pull on a guy line. They depend on skin friction alone for their support.

Lateral (Force resisting) piles.--This type of pile resists horizontal forces like the pull of guy and anchor lines, or the pressure of retained embankments. The most common type is sheet piling. Sheet piling is driven to prevent the lateral movement of water and/or adjacent soil material. Its principal uses are in lining ditches, retaining walls, cut-off walls, revetments and cofferdams.

Piling Materials.

Wood piles.--Wood is one of the most common materials used for piling. Round timber is normally used for bearing piles; dimension lumber or steel for sheet piling. Wood piles may be Douglas Fir, Yellow Pine, Redwood, Southern Cypress, or other species. They need very little preparation, but when round timber is used, they should be cut from straight, sound trees and should be free from large or loose knots and from any other defects which could impair their strength or durability. They should have a uniform taper from butt to tip. A straight line from the center of the butt to the center of the tip should be within the body of the pile. Unless otherwise allowed, piles should be cut when the sap is down and peeled soon after cutting. The kind and amount of preservative treatment, and other special requirements, should conform to the requirements of the drawings and specifications.

Steel piles.--Rolled-steel section, steel pipe and railroad rails are often used for piles. The most common shapes for bearing piles are the H and I Section. Special shapes are manufactured for steel sheet piling.

Concrete piles.--Cast-in-place piles may be drilled holes filled with concrete or a steel shell which is driven into the ground and later filled with concrete. Precast piles are reinforced concrete members that are cast and thoroughly cured before driving. The precast piles may be driven with a hammer similar to those used for timber piles. Under certain conditions, a water jet may be approved to assist driving. With the scarcity of timber and the improvements in concrete, reinforced concrete bearing piles are being used extensively for all types of structures.

Delivery and Storage.

Material check.--When the piles arrive on the job, the inspector should determine that they are in satisfactory condition and meet all of the requirements of the drawings and specifications. Unsatisfactory piles should be plainly marked. An entry should be made in the Job Diary if piles are rejected stating number of piles, kind of material, dimensions and reason for rejection.

Unloading.--Piles should be unloaded in such a manner that they will not be damaged. All operations are performed in compliance with all safety regulations. A crane should be used to unload concrete piling. Piling should be picked up at two or more points with an equalizer to prevent undue strain at any point on the pile. When "H" piles are being unloaded, the use of a safety hook on each end of a lifting beam is desirable to hold the pile securely during the lifting operation.

Storage.--Storage yards should be free of obstructions and overhead wires. Piles should be stored in a place easily accessible for trucks or other means of delivery. They should be stacked in an orderly manner on timber blocking so that the axis of the pile is in a straight line and properly braced so that there will be no danger of their falling or rolling. Materials should be removed in such a way that other piles will not roll. Precast pile must be placed on level blocks spaced at the pickup points. It cannot be too strongly emphasized that a clean, well-arranged material storage area is essential to safe and efficient pile driving operations.

Driving Equipment.

General.--Pile drivers may be classified as land drivers or floating drivers. For use on land, the trend is toward the mobile crawler or truck mounted crane. Any crane can be equipped with a set of fair leads, spotter, hammer and accessory equipment. Special built drivers are equipped for driving batter pile. The purpose of the pile driver is to support the pile and hammer in a fixed position during driving. The rig must be stable and of adequate capacity to lift the pile and to handle both pile and hammer without swaying during driving. The leads should be long enough to drive the pile in one complete operation.

Drop hammers.--The drop hammer, although the oldest type, is fast becoming obsolete. The main disadvantages are (1) the slow rate of driving which may allow for some temporary set of the pile, and (2) use of too great a height of fall, the resulting high-velocity impact stresses often causing the head of the pile to fracture and in some cases internal failure of the pile. These hammers usually range from 1,000 to 5,000 pounds in weight.

Single acting hammers.--This type of hammer, often called the vulcan type, is powered by steam or air pressure which raises the ram weight, which then falls by gravity. The common ram weights are 5,000 to 6,500 pounds. Not always are these weights the correct size for the job; but for average driving conditions, they are adequate.

The setting of the valve is the main point to check during operation. Improper timing can permit steam or air to be admitted to the lower side of the piston before it reaches the end of the downstroke to act as a cushion or the valve can cut off too soon resulting in a short upstroke of the hammer. A single acting hammer in good condition, working under adequate driving pressure, should deliver 50 to 55 blows per minute.

Any type of power driven hammer that does not operate to the satisfaction of the inspector should be taken out of operation until it is properly adjusted or reconditioned.

Double acting hammers.--These hammers use steam or air to raise and to impart energy to the driving ram. The action is faster, but the hammer will have a lighter ram than the single acting hammer for an equally rated energy per blow. Uniform pressure is required to assure rated capacity and the condition of the valve setting and also the condition of the rings and cylinder walls have direct influence on the effectiveness of the blow.

Differential hammers.--This type unit uses air or steam to deliver extra energy to the falling piston which has two different diameters and the force of the steam or air added to the falling ram is the unit steam pressure multiplied by the difference in the areas of the two pistons. The operating speed of this hammer is about 75 percent faster than for the same weight ram in the single acting unit.

Diesel hammers.--In this type hammer, the ram is the cylinder of the hammer and is free falling. Compression takes place within the cylinder on the downward stroke of the ram and tends to cushion the blow. It is a desirable hammer because of compactness and simplicity. However, it has the disadvantages of not being a self starting unit, and it does not deliver a uniform blow.

Stroke.--The stroke or fall of a hammer determines the energy or impact delivered. On modern steam hammers, the slide bar can be fixed to deliver a constant blow, and it can be adjusted to increase or soften the impact. No hammer should be allowed to operate with a loose slide bar.

Weight of ram.--A heavy ram working on a short stroke is usually more effective than a lightweight long stroke hammer. For proper driving, it is important to consider the weight of the hammer, the stroke and speed, and their relation to the weight of the pile.

Driving heads.--Driving heads fabricated from steel are shaped to fit the particular pile or sheeting being driven. They protect the pile head and transmit the blow of the hammer.

Cushion blocks.--Cushion blocks, made of hardwood, plywood or other composition, are placed on top of the driving heads to soften the blow of the hammer just enough to prevent injury to the head of the pile. It is important that a satisfactory cushion material is used as a real soft wood may act as a sponge in absorbing the energy of the hammer, and some hardwoods tend to splinter and lose effectiveness. Wood blocks should be cut to size with the grain vertical and must be removed when they have been compressed to more than half of their original thickness. They should also be replaced when they heat up to the point they start smoking.

Jets.--A stream of water under pressure may be required to facilitate driving of a pile into some soils. Usually the jet is worked along the side of the pile, and must be designed for the soil condition encountered. In granular soils a balanced jet having holes which distribute an equal upward and downward cutting force should be used. In cohesive soils a straight pressure velocity does the cutting action. The amount of jetting should be limited to the bare requirement for placing the pile. Overuse may reduce the friction on the pile being driven and may loosen the soil around other piles already in place. The use of jets are not recommended for driving piles in real coarse gravels. Jetting in these materials may remove the fines and permit the coarse material to concentrate in the hole.

<u>Determination of Bearing Capacity</u>.
General.--Specifications for capacity or driving requirements for the piles may be specified by one of the following methods:

(a) Depth of penetration.

(b) Safe bearing capacity determined by dynamic pile formula.

(c) Pile length and size determined from loading of test pile driven at the site.

The inspector must be familiar with the requirements of the contract and the proper method of field procedure.

Depth of penetration.--The procedure of driving piles to a required depth of penetration does not have wide application in design of Service projects, except for end bearing piles which are driven more or less to refusal to make proper contact with predetermined supporting strata. Extra care must be exercised that end bearing piles are not damaged by overdriving.

Capacity by formula.--It is common practice that friction piles be driven to specified safe bearing value as determined by formula. The contract should outline the capacity requirements, procedures to be used, and the formula for computing the required bearing value. Many formulas have been developed, however, it may be said that no dynamic formula will give the true static bearing value of a pile. This value can be determined only by a load test.

The dynamic pile driving formula having the most common usage is the "Engineering News Formula" which has three forms:

1. For gravity (drop) hammer: $R = \frac{2\ WH}{S + 1.0}$

2. For single-acting steam and diesel hammers having unrestricted rebound of the ram: $R = \frac{2\ WH}{S+0.1}$

3. For double acting steam and diesel hammers having enclosed rams: $R = \frac{2H\ (W + AP)}{S+0.1}$ or

   $R = \frac{2E}{S+0.1}$

Where:

R = Safe bearing capacity in pounds.

W = Weight, in pounds, of striking parts of hammer.

H = Height of fall in feet.

A = Area of piston in square inches.

P = Pressure, in pounds per square inch, of steam or air exerted on the hammer piston or ram.

E = The manufacturer's rating for foot pounds of energy developed by double-acting steam or air hammer, or 90 percent of the average equivalent energy, in foot pounds, developed by diesel hammers having enclosed rams as evaluated by gauge and chart readings.

S = Average penetration, in inches per blow, for the last 5 to 10 blows of a gravity hammer, or the last 10 to 20 blows for steam, air or diesel powered hammers.

The major value of determining the value R for each pile driven is that it serves as a measure of uniformity for all of the piles driven. Complete documentation should be made of all field driving data and calculations, when the formula method is specified, to verify that the contractor has driven each pile to the required bearing capacity.

Capacity by load test.--Load testing consists of applying increment loads up to, usually twice the design load for the pile, and leaving the maximum applied load for a specified number of hours. The pile may be considered to have a safe bearing value equal to the design load if the permanent settlement after testing does not exceed a specified amount, generally 1/4 inch is acceptable. Test loads may be applied by direct vertical static contact with the pile head, using sand, steel ingots or concrete, resting on a rigid platform placed over the pile, or loads may be applied by jacks operating between the head of the pile and an attached beam anchored to piles driven either side of the pile to be tested. The contract should outline detail procedure when actual load tests are required and the acceptable performance of the test pile. Field notes (see Figures 5-5 and 5-6) may be used to record data for the installation of each test pile.

Driving records for load test piles should include:

1. Piling location (number).

2. Date driven.

3. Kind of pile material (if wood, indicate kind).

4. Tip diameter.

5. Butt diameter.

6. Diameter at ground line.

7. Length of pile (nearest 0.1 foot).

8. Penetration per blow (nearest 0.1 foot).

9. Number of blows per foot, record for total penetration.

10. Hammer data (complete description, size, type, fall, pressure, etc.)

11. Record time required for driving - note any shutdowns, why.

Test piles should be driven without the use of jets; if a jet is used, all information on the jetting procedure should be recorded.

Inspector's Check List.
Prior to driving.--

1. Determine if pile is friction or end bearing.

2. Ascertain if pile is to be driven to refusal, a specified bearing, or depth.

3. Check that each pile meets specifications when delivered to site - and that rejects are properly marked. Make detail record in Job Diary on reject items.

4. See that correct pile lengths and diameters are recorded for each pile.

5. Make sure driving equipment is adequate and complete - study hammer manufacturer's performance and operations releases - see that steam boiler inspection certificates have been kept up to date - check all steam or air equipment frequently for safety. Do not allow driving to start until equipment has been approved, including weight and type of hammer.

6. Check pile layout plan - start driving in the center and move in concentric pattern for close space design.

7. See that pile is properly tipped, heads wrapped or banded, and cut smooth and normal to the longitudinal axis.

8. Determine that satisfactory head fits snugly and uniformly on pile. Be sure rebars in concrete pile do not receive blow of hammer.

9. Check that satisfactory cushion blocks are available.

10. Determine that material certificates have been received for pile materials.

During driving.--

1. See that pile is transported, lifed and placed in position so that overstressing or twisting damage does not occur.

2. Pile and fair leads should be properly guyed or supported to prevent sway during driving.

3. Observe behavior of pile while driving, compare with boring log - watch for reactions which indicate broken piles.

4. Keep free fall of drop hammers within limits of the specifications.

5. Check steel driving shoes on wood or concrete pile - determine damage by pulling an occasional pile.

6. Once started, keep pile moving - record length of delay and tip elevation at time of any suspension of work.

7. Check for heave of earth and surrounding piles as driving progresses.

8. Record elevation of pile when driving is complete and recheck at later date for possible heave.

9. Do not permit splicing of pile without proper approval.

10. Use adequate template or bracing to guide pile when driving without leads.

11. Do not permit driving in close vicinity of newly placed concrete, until design strength has been reached.

Jetting.--

1. Determine maximum depth that jetting is permitted.

2. Watch for change in alignment and looseness of piles previously driven.

3. Redrive piles after jetting in area is complete.

4. Watch for damage to adjacent structures if jetting is permitted.

Driving for resistance.--

1. See that drop hammer is operated through uniform distance of fall, and within the limits of maximum drop specified.

2. See that ram is operating at full stroke, rated speed and under full recommended pressure.

3. Watch for any slowdowns in hammer operation.

4. Require good cushion block material at all times.

5. Determine penetration by noting number of blows required to drive pile a predetermined distance.

Overdriving.--

1. Do not overdrive to meet a specified depth - consult with your superior if driving conditions change materially - may have to use shorter, longer, or even additional pile.

2. Check sound and vibration of pile for evidence of damage.

3. Watch for bounce of hammer or kicking of pile as an indication of overdriving.

Tolerances.--

1. Maintain close check on sheet piling for location and vertical position. Closures and connectors may require driving to fine tolerance.

2. See that permissible tolerance for other pile is maintained.

3. Do not permit overstressing of pile to correct alignment.

4. Check that pile is driven to correct elevation.

5. See that piling is not trimmed or cut to facilitate framing of sway or longitudinal bracing.

Records.
A complete record should be maintained for all piles furnished and for each pile installed. Form SCS-545, "Pile Driving Record", Figure 5-3, may be used to maintain a cumulative record of installation. Field Survey Notebooks, made up with proper headings, may be used to record daily driving operations. See Figures 5-4 and 5-5.

Detail records for driving and load tests on "Test Piles" should be recorded in the pile driving field notebook, using a format similar to that illustrated in Figures 5-5 and 5-6.

NATIONAL ENGINEERING HANDBOOK

SECTION 19

CONSTRUCTION

CHAPTER 4. SAMPLING AND TESTING

The sampling and testing procedures presented in this chapter are methods that are common to the industry and have general application for construction operations inspected by Service personnel.

It is important to recognize that sampling and testing procedures mentioned directly or by reference in the contract specifications may on occasion conflict with methods or suggestions presented in this handbook. When this situation occurs the test procedures set forth in the contract have priority and should be followed.

SOILS

Test No. S-1

Identification by Field Tests

General.
Correct soil identification is essential for proper control of construction for earth dams and other related structures. The ability to identify soils in the field by simple visual and laboratory procedure is essential to construction personnel, since decisions may be required within time limits that do not permit processing samples through the regular laboratory procedures. In addition to the ability to identify soils, it is also desirable that construction personnel have some knowledge of the behavior of different soils and their suitability for use in construction. Soils in nature seldom exist separately as basic types but are found as composites which may consist of various combinations of gravel, sand, silt, clay or organic matter. It is important that a field classification be made when a sample is taken for laboratory tests to gain practice and confidence in the identification of soils.

The following field tests were developed largely by Professor A. Casagrande, Graduate School of Engineering, Harvard University, and have been widely adopted for use in identification of soils. The test methods included are excerpted from publications issued by the Department of the Army.

Observations and results of the field tests may be recorded on the visual soil classification form, Figure 4-1, Form SCS 542.

Procedures for making the tests are as follows:

Test Methods.

Grain shape.--Observe and classify the gravel, 3" to #4 sieve (approximately 1/4"), and sand, #4 to 200 sieve (0.074mm.) particles as to degree of angularity or roundness. See Figure 4-2, (2-a).

Grain size and gradation.--Sand and gravel sizes are readily identified by visual inspection. Individual grains below the smallest size cannot be seen by naked eye and must be identified by other tests. For gradation of coarse grained soils, spread a representative sample on a flat surface and observe the distribution or uniformity of grain sizes. Observe the proportion of fines and subject the fine grained fraction to all tests described for fine grained soils.

Often the field laboratory has standard sieve sizes available that may be used to evaluate the grain size distribution of a representative soil sample. Procedures outlines in Test C-7, as they apply, may be used to make the size separations. Results of the sieve test may be shown graphically on Form SCS-353a, (Figure 4-33), thereby making it possible to check the field sample with the laboratory grain size graph used in design.

Identification criteria.--

A. Coarse grained soils - If more than half of the particles by weight are larger than the No. 200 sieve (about the smallest particle visible to naked eye at a distance of about 10 inches) then the soil would be classified as a coarse grained soil; under the Unified Classification System; GW, GP, GM, GC, SW, SP, SM, SC, gravels, clayey and silty gravels, silty sands, clayey sands, sands, etc. The differentiation between gravel (G) and sand (S) depends on particle size. Samples containing more than 50 percent by weight passing the #4 sieve are classified as sand. Weak casts can be formed from moist SM or SC soils, however, dry clods fall apart easily.

B. Fine grained soils - If more than 50 percent of the sample by weight is smaller than the No. 200 sieve, the soil would be classified as a fine grained soil. Fine grained soils may consist of silt, clay and organic particles. Silts lack plasticity and have little or no dry strength. Clays contain colloidal scale-like particles, which are the cause of plasticity. Dry strength and plasticity are affected by shape and mineral composition of the particles. Organic matter consists of either partly decomposed or finely divided vegetable matter and is an identifiable factor in the organic silts and clays - OL and OH.

C. Gradation of the fine grained soils can be estimated by shaking a sample in a jar of water and observation of the mixture as it settles. Approximate gradation is indicated

SCS-542
(Rev. 11-19-64)

MATERIALS TESTING SECTION REPORT

VISUAL SOIL CLASSIFICATION

PROJECT	LOCATION	SAMPLED BY	TESTED BY

INDENTIFICATION				COARSE FRACTION					FINE FRACTION					TOTAL SOIL			CLASSIFICATION	
TESTING SECTION SAMPLE NO	TEST HOLE NO.	FIELD SAMPLE NO.	DEPTH IN FEET	MAXIMUM SIZE (MM)	GRAV (PLUS +4)	SAND (#4 to #200)	PARTICLE SHAPE	PARTICLE CONDITION	FINES MINUS (#200)	PLASTICITY	DRY STRENGTH	DILATANCE	REACTION TO BENZIDINE	ORGANIC ODOR (WET)	REACTION TO HCL	COLOR (WET)	DESCRIPTION (Descriptive classification, grading, structure, consistency, moisture condition, inclusions etc.)	GROUP SYMBOL

Remarks	U.S DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE	Signature	
		Title	Date

Figure 4-1

STANDARD DESCRIPTIONS OF IDENTIFICATION TEST REACTIONS

TEST	DESCRIPTION	SYMBOL	IDENTIFICATION OR TEST REACTION
PARTICLE SHAPE	Angular	A	Irregular shape; sharp edges.
	Subangular	SA	Irregular shape; fairly sharp edges.
	Subrounded	SR	Irregular shape; rounded edges.
	Rounded	R	Fairly regular shape; rounded edges.
PARTICLE CONDITION	Hard	H	Rubber pestle will not break particles.
	Soft	S	Rubber pestle will break particles.
	Vesicular	V	Individual grains contain air voids.
	Dense	D	Massive; grains contain no air voids.
PLASTICITY	High	H	Tough thread, will remold below PL.
	Medium	M	Medium tough thread, crumbles below PL.
	Low	L	Weak thread, will not remold at PL.
	None	N	Will not form thread.
DRY STRENGTH	High	H	Difficult to break by finger pressure.
	Medium	M	Cosiderable finger pressure to crumble.
	Low	L	Will crumble at light finger pressure.
	None	N	Will not form soil pat.
DILATANCE	Rapid	R	Water surfaces immediately.
	Slow	S	Water surfaces slowly.
	None	N	Water will not surface.
BENZIDINE	Positive	+	Formation of blue color.
	Negative	−	No color change.
HCL	Positive	+	Effervescence
	Negative	−	No reaction
ORGANIC ODOR	Strong	S	Strong odor when moist and hot.
	Weak	W	Weak odor when moist and hot.
	None	N	No organic odor

SOIL IDENTIFICATION CRITERIA

GROUP	ORGANIC ODOR	VISUAL EXAMINATION			CHARACTER OF FINES (Minus #40)		
		GRADING	% FINES	DOMINANT FRAC.	DILATANCE	DRY STR.	PLASTICITY
ML	Weak	Not a criterion for classification	Over 50%	Fines	Rapid	Low	None-Low
CL-1	"		"	"	Slow	Low-Med.	Low
CL-2	"		"	"	None	Med.-High	Med.
CH	"		"	"	None	High	High
MH	"		"	"	None-Slow	Low-Med.	Low – Med.
OL,OH	Strong		"	"	None	Low-Med.	Med (Spongy)
SM	Weak		12%-50%	Sand	Fines classify as ML or MH		
GM	"		"	Gravel			
SC	"		"	Sand	Fines classify as CL or CH		
GC	"		"	Gravel			
SP	"	Poor	Under 5%	Sand	Not a criterion for classification		
GP	"	"	"	Gravel			
SW	"	Well	"	Sand			
GW	"	"	"	Gravel			
Pt	Strong	Indentify by high fibrous organic content.					

Figure 4-1 (Cont.)

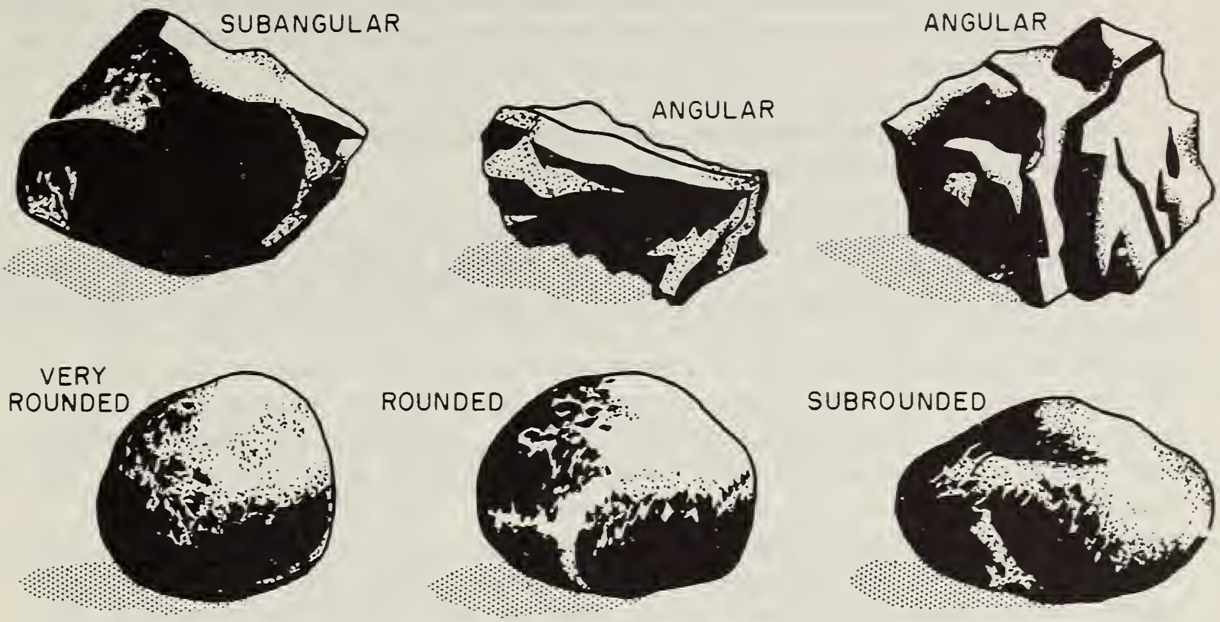


FIGURE 2a. GRAIN SHAPE

Method of shaking

FIGURE 2b. SHAKING TEST

Method of crumbling soil between fingers

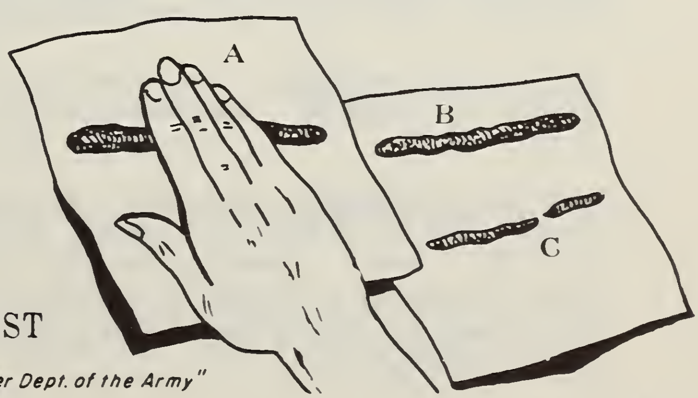
FIGURE 2c. BREAKING TEST

A. Method of rolling thread.

B. Thread of soil above plastic limit.

C. Crumbling thread as plastic limit is reached.

FIGURE 2d. PLASTICITY TEST



"After Dept. of the Army"

7-L-14373

Figure 4-2

by the separation of the particles from top to bottom. Silt remains in suspension for at least one minute, clay one hour or more.

Note: Tests performed on fine grained samples should be limited to materials passing the #40 sieve.

Dilatance (shaking test).--A pat of moist soil (try several pats with different moisture contents) is shaken horizontally in the palm of the hand, see Figure 4-2, 2-b. An even uniform motion of the hand containing the sample should be used for all tests. This action should be supplemented by a lightbumping action against the palm of the other hand. Observe if water comes to the surface of the sample, making it appear soft and glossy, squeeze the sample between the fingers, causing the moisture to disappear from the surface which changes from a shiny to a dull appearance. At the same time the sample stiffens and finally crumbles under increasing finger pressure; shake the broken pieces until they become livery and flow together again. Distinguish between slow, medium and rapid reaction to the shaking test.

Rapid reaction - indicates lack of plasticity - typical of inorganic silt, rock flour, or very fine sand - ML, SM, (shaking action limited to four or less).

Slow reaction - plastic silt or silty clay - CL (four to eight shaking motions required).

Very slow to none - MH (requires more than eight shaking motions).

No reaction - indicates clay or peaty (organic) material, CH, OH.

Dry strength (crushing test).--The crushing test may be used to determine the dry strength, which is a measure of the cohesiveness of the soil.

Allow a wet pat of the soil to dry and test its dry strength by crushing between the fingers, see Figure 4-2, (2-c). Distinguish between slight, medium and high strength.

Slight dry strength - indicates an inorganic silt, rock flour or silty sand. However, the sand feels gritty when sample is powdered. ML, fine grained SM and SC.

Medium dry strength - considerable pressure is required to powder the sample. Indicates a low to medium plastic inorganic clay - MH.

High dry strength - indicates a highly plastic, inorganic clay. Sample can be broken but cannot be powdered by finger pressure. CL - CH. Note: Cohesion or high dry strength may result from some cementing material such as calcium carbonate or iron oxide. For example - non plastic lime rock or coral may develop high dry strength.

Plasticity (toughness test).--Plasticity is the physical property of a fine grained soil which allows it to be kneaded into a putty-like consistency at the proper moisture content. To test plasticity of a soil, prepare a moist pat. Start rolling it out with the palm of the hand on a flat surface into approximately 1/8 inch threads, Figure 4-2, (2-d). Fold the threads into a lump, roll into a thread, and repeat the process until moisture loss causes thread to crumble when rolled. The moisture content at this stage is called the plastic limit. Note the toughness of the threads as the plastic limit is reached, and test if the crumpled pieces can be lumped together again.

<u>High plasticity</u> - forms a tough thread which can be remolded into lump below the plastic limit and deformed under finger pressure without crumbling. CH, CL.

<u>Medium plasticity</u> - soil forms a medium tough thread, but the remolded lump crumbles soon after the plastic limit is reached. CL, MH.

<u>Low plasticity</u> - soil forms a weak thread that cannot be remolded below the plastic limit, CL, and some ML. Plastic soils containing organic material or quantities of mica form threads which are soft and spongy, OH, OL.

When the liquid limit or plastic limit are determined by laboratory methods and equipment, the results may be recorded in the "Plasticity" column, figure 4-1, ie LL = 30 PL-10 or regular laboratory report forms may be used to supplement the field visual classification report.

Shine test.--Rub a dry or slightly moist sample with the fingernail or a knife blade.

<u>Shiny surface</u> - Indicates a highly plastic clay, CH.

<u>Dull surface</u> - Indicates a silt or clay of low plasticity, ML, CL, OL.

Odor test.--Freshly sampled organic soils usually have a distinctive odor which aids in their identification. The odor can be made more apparent by heating a wet sample.

Acid test.--Drop a little hydrochloric acid on a piece of soil. A fizzing reaction indicates calcium carbonate.

Refer to Figure 4-3 for more detail characteristics and uses for the various soil groups.

Questionable soils should be tested by laboratory facilities. The laboratory tests are designed to give the same information as the field tests, but they are far more definite and conclusive.

Field Identification Procedures

No. 200 sieve size is about the smallest particle visible to the naked eye.

Major division	Fines	Subdivision	Description
COARSE GRAINED SOILS — More than half of material (by weight) is of individual grains visible to the naked eye.	CLEAN LITTLE OR NO FINES — Will not leave a dirt stain on a wet palm	Gravels (more than 50% larger than #4)	Wide range in grain sizes and substantial amounts of all intermediate particle sizes.
			Predominantly one size or a range of sizes with some intermediate sizes missing.
		Sands (more than 50% smaller than # 4)	Wide range in grain size and substantial amounts of all intermediate particle sizes.
			Predominantly one size or a range of sizes with some intermediate sizes missing.
	WITH APPRECIABLE FINES (more than 12%) — Will leave a dirt stain on a wet palm	With Plastic Fines	Gravel with plastic fines (for identification of fines see characteristics of CL and CH below.
			Sand with plastic fines (for identification of fines see characteristics of C L and C H below.
		With Non-Plastic Fines	Gravel with nonplastic fines or fines with low plasticity (for identification of fines see characteristics of M L and M H be-low).
			Sand with nonplastic fines or fines with low plasticity (for identification of fines see characteristics of M L and M H below).

For visual classification the 1/4 in. size may be used as equivalent to the No. 4 sieve size.

See Identification Procedures

Major division	Group	ODOR	DRY CRUSHING STRENGTH	DILATANCY (SHAKE) REACTION	TOUGHNESS	RIBBON (NEAR THE P.L.)	SHINE (NEAR THE P.L.)
FINE GRAINED SOILS — More than half of material (by weight) is of individual grains not visible to the naked eye.	SILTS AND CLAYS (Low Plastic)		Slight	Rapid	Low to None	None	Dull
			High	Medium to slow	Medium	Weak	Slight to shiny
		Pro-nounced	Medium	Slow to None	Low	None	Dull to Slight
	SILTS AND CLAYS (Highly Plastic)		Medium	Very Slow to None	Medium	Weak	Slight
			Very High	None	High	Strong	Shiny
		Pro-nounced	High	None	Low to Medium	Weak	Dull to Slight

HIGHLY ORGANIC SOIL	Readily identified by color, odor, spongy-feel and frequently by fibrous texture.

Figure 4-3

Suitability for Embankments	Value for Foundation (Seepage Control)	Typical Names
Very stable - pervious shells of dikes or dams.	Good bearing value (Requires positive cut-off)	Well graded gravels, gravel-sand mixtures, little or no fines.
Reasonably stable, pervious shells of dikes and dams.	Good bearing value (Requires positive cut-off)	Poorly graded gravels, gravel-sand mixtures, little or no fines.
Very stable, pervious sections, slope protection required.	Good bearing value Upstream blanket and toe drains	Well graded sands, gravelly sands, little or no fines.
Reasonably stable, pervious sections with slope protection.	Good to poor - depends on density - (blanket and toe drains)	Poorly graded sands, gravelly sands, little or no fines.
Fairly stable - may be suitable for impervious core.	Good bearing value (none)	Clayey gravels, gravel-sand-clay mixtures.
Fairly stable, impervious core, flood control structures.	Good to poor (none)	Clayey sands, sand-clay mixtures.
Reasonable stable - limited use for impervious core or blankets.	Good bearing value (Toe trench to none)	Silty gravels, gravel-sand silt mixture.
Fairly stable - not particularly suited to shells, may be used for impervious cores or dikes under limited conditions.	Good to poor bearing value depending on density (upstream blanket and toe drainage).	Silty sands, sand-silt mixtures
Poor stability - may be used for embankments with proper design and control in placing.	Fair to very poor Susceptible to liquefaction (Toe drainage to none)	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
Stable - impervious cores and blankets.	Good to poor (none)	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
Not suitable for embankment.	Fair to poor bearing, excessive settlement may result (none).	Organic silts and organic silty clays of low plasticity.
Poor stability - not desirable in core rolled fill embankments.	Poor bearing (none)	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
Fair stability with flat slopes thin cores, blankets and dikes.	Fair to poor bearing (none)	Inorganic clays of high plasticity, fat clays.
Not suitable for embankments.	Very poor bearing (none)	Organic clays of medium to high plasticity, organic silts.
Do not use for construction.	Remove from foundations	Peat and other highly organic soils.

Figure 4-3 (Cont.)

SOILS IDENTIFICATION AND CONSTRUCTION PROPERTIES
(continued)

Unit Dry Wt. Lbs. per Cu. Ft. (ATSM D-698)	Compaction Characteristics	Suggested Compaction Equipment	Unified Soil Classes
125-135	Good	Tractors, rubber tired equipment Vibrating Compactors or Grid type rollers	GW
115-125	Good	" " " " " " " " "	GP
110-130	Good	" " " " " " " " "	SW
100-120	Good	" " " " " " " " "	SP
115-130	Fair	Rubber tired, sheepsfoot or grid rollers	GC
105-125	Fair	Sheepsfoot or rubber tired rollers	SC
120-135	Good - with close control	Rubber tired, sheepsfoot or grid rollers Vibrating compactors	GM
110-125	Good - with close control	Rubber tired, sheepsfoot or grid rollers Vibrating compactors	SM
95-120	Good to poor	Rubber tired or sheepsfoot rollers	ML
95-120	Fair to good	Sheepsfoot or rubber tired rollers	CL
80-100	Fair to poor	- - - - - - - - - - - - - - - - -	OL
70--95	Fair to very poor	Sheepsfoot roller	MH
75-105	Fair to poor	Sheepsfoot roller	CH
65-100	Poor to very poor	- - - - - - - - - - - - - - - - -	OH
	Compaction not practical	- - - - - - - - - - - - - - - - -	Pt

Figure 4-3 (Cont.)

United States Department of Agriculture
Soil Conservation Service
Engineering Division

Technical Release No. 27
February 4, 1965

Laboratory and Field Test Procedures for Control of Density and Moisture of Compacted Earth Embankments

The purpose of this technical release is to coordinate procedures used for controlling moisture and density of compacted earth materials in laboratory testing operations and field construction control.

The kinds and details of tests vary with kinds of soil involved.

A. Fine-Grained and Non-Gravelly Soils (less than 5% rock larger than No. 4 sieve).

All laboratory and construction control tests will be based upon the moisture-density relationships of soil processed to pass a No. 4 sieve.

Compaction requirements will call for Compaction Class A controlled to a specified degree of maximum density obtained by ASTM Test Designation D-698 or D-1557 - Methods A or B.

Design values will generally be determined by testing soil compacted to the specified percentage of maximum density obtained by the Standard (D-698) compaction test. Higher compactive efforts, e.g. Modified Compaction, D-1557, may be used to determine the compacted properties of some highly plastic (CL and CH) soils. In such cases, design values will generally be determined by testing soil compacted to 90% of maximum "modified" density.

Field Compaction Control: The dry density and moisture content of the compacted fill will be determined by using density tests S-2 (Sand Cone), S-3 (Rubber Balloon), S-4 (Calibrated Cylinder), S-5 (Kerosene), and moisture tests S-10 (Oven), S-11 (Quick Dry), S-12 (Alcohol), or S-13 (Speedy Moisture Meter) given in NEH, Section 19 - Construction.

The degree of compaction of material in the fill is determined by computing the ratio of in-place embankment density to maximum density of the same material determined by moisture-density tests S-6 (Rapid Method), S-7 (ASTM D-698), or S-8 (ASTM D-1557) given in NEH, Section 19.

Results from moisture-density tests (S-6, S-7, or S-8) previously determined may be used as basis for computing degree of compaction in the fill provided (a) materials tested in the fill are essentially the same - based on standard unified soil classification field tests - as those for which moisture-density curves were previously developed and (b) the moisture content of material tested in the fill is near optimum and the density value determined by compacting one mold of material at placement moisture taken from

the immediate area of the in-place embankment test falls on or very near the predetermined moisture-density curve (using the same procedure for both compaction tests).

It is always advisable to develop moisture-density curves on the job for each kind of material excavated for use on the fill. Soil masses are too variable to expect that all material excavated from a specific borrow source will be exactly like the small sample tested in a laboratory. If the maximum density of a job curve varies significantly from that used in the design of the embankment, this fact should be brought to the attention of the design engineer immediately to be sure the material fulfills design requirements.

Many materials excavated from specific borrow sources are variable from load to load. Variations in materials may be due to stratification, irregular topography and depth, spotty and irregular areal patterns of deposition or other causes. In such cases, complete moisture-density curves should be developed as a basis for computing the degree of embankment compaction. These compaction tests should be made using soil taken from the immediate area around the in-place embankment density test excavation. Three or more individual compaction test molds will generally be required to define the maximum density-optimum moisture values for each sample. A new portion of the sample may be used for determining each point on the moisture-density curve if this is more convenient than reusing the same portion for each point as prescribed in Tests S-7 and S-8.

There will undoubtedly be many situations where variations in borrow material that appear to be significant will have little effect upon maximum density-optimum moisture relationships and moisture-density curves developed for a number of in-place embankment density test sites will be essentially the same. In such cases, these previously determined moisture-density curves may serve as a basis for using "one-point" moisture-density tests previously discussed for use in uniform soils.

B. Coarse-Grained Soils - Group I: Gravelly and stony soils (more than 5% larger than No. 4 sieve) with hard, durable rock.

1. Sub-Group IA - Soils with more than 65% passing No. 4 sieve ($<$ 35% rock).

   Design and construction control tests will be based upon moisture-density relationships of the soil matrix. The soil matrix is defined as that fraction of the soil-rock mixture having a maximum size equal to that used in the compaction test method.

   Compaction requirements will call for Compaction Class A controlled to a specified degree of maximum density obtained by performing ASTM Test Designation D-698 or D-1557.

Design Values will generally be determined by testing the soil matrix compacted to 95% of maximum Standard density (D-698). When it is desirable to obtain different engineering properties, higher compactive efforts may be used.

Field Compaction Control.

The in-place density and moisture content of the compacted fill will generally be determined according to Test S-2, Alternate A, NEH, Section 19.

The moist weight and volume of the total sample will be determined, after which the total sample will be screened or washed through a No. 4 or 3/4" sieve, depending on the method used. The moisture content should be determined on a representative sample of the soil matrix. The moist weight and volume of the rock is determined. The volume of the rock should be measured by displacement in a siphon can or a graduated cylinder. Details on separating and measuring the volume of the rock are covered in Appendix I. The weight of moist rock should be deducted from the total moist weight of sample and the volume of rock deducted from the total volume of sample, after which the approximate moist weight, volume, and moist density of the soil matrix can be computed. The dry density of the soil matrix is then computed, using the moist density and moisture content values.

The degree of compaction will be computed as the ratio of in-place dry density to maximum dry density obtained by performing specified tests on the soil matrix taken from and immediately around the in-place density test excavation. As discussed under Fine-Grained Soils, Part A, if the soil matrix of the soils from a specific borrow source is uniform in gradation and composition, comparison of results from one compacted mold or specimen with a complete compaction curve previously developed may be adequate to define the maximum compacted density for that particular test.

2. Sub-Group IB - Gravelly and stony soils with 65% to 35% passing No. 4 sieve (35% to 65% hard, durable rock).

   a. Laboratory tests and design values.

      Tests on the minus 3/4-inch fraction of the soil-rock material will generally be used as the basis for design when all borrow materials have about the same gradation characteristics in the fraction passing the 3/4-inch sieve and the total material contains less than 35% rock larger than 3/4-inch size.

      Laboratory tests will generally be performed on specimens of the minus 3/4-inch fraction compacted to 95% of maximum

density obtained by ASTM D-698, Method C or D. When it becomes desirable to obtain different engineering properties, higher compactive effort may be used.

Mass density may be used as the basis for design tests when proposed borrow materials are quite variable in the gradation of the minus 3/4-inch fraction - or have more than 35% larger than 3/4-inch. In such cases, laboratory tests will be performed on materials passing the 1-inch or 3-inch sieve compacted to an arbitrary base density of the mass with varying amounts of rock. The base density of the mass will generally be established as 95% of maximum density of the minus No. 4 fraction compacted by ASTM D-698 and adjusted for 40% rock.

When considerable variation in the rock content of borrow materials is indicated by investigations, the design should be based on the characteristics of the material in the least desirable condition of rock content. Specifications can then call for random fill from the specified borrow sources.

b. Field compaction control.

Care in selecting and judging a representative site for in-place density tests is very important with these types of materials. Details on this subject are covered in Appendix I.

When Class A compaction is specified, in-place density tests will be made in accordance with Test S-2 (ASTM D-1556, Sand Cone), NEH, Section 19, or by using plastic lining and water to measure the volume of the test hole as described in Appendix I. The moist weight and volume of the total sample will be determined, after which the total sample will be screened through a 3/4-inch sieve. The moisture content should be determined on a representative sample of the minus 3/4-inch fraction. The moist weight and volume of the rock larger than 3/4-inch will be determined and subtracted from values for the total sample. The preferred method of determining the volume of plus 3/4-inch rock is to measure displacement in a siphon can or graduated cylinder. This method may not be practical when the plus 3/4-inch rock exceeds 3 inches to 4 inches in diameter. When the rock is uniform in composition, the volume of rock may be computed by dividing the dry weight of rock by the bulk density of the rock, as given in laboratory reports or determined by Test S-15, NEH, Section 19.

The maximum density of the minus 3/4-inch fraction should be determined by Test S-7, NEH, Section 19 (ASTM Test D-698 or D-1557, Method D) on material taken from and immediately around the in-place density test excavation.

When compaction of the fill is controlled by the specification of the type of equipment and the number of passes per lift, sufficient density tests should be made to insure that the specified compaction methods obtain the desired results. In-place density tests will be performed by the same procedures described for control of Class A compaction. Control will usually be based on determination of the density of the fill matrix (minus 3/4-inch fraction). Determination of mass density may suffice for checking the condition of random fill from selected borrow sources.

3. <u>Sub-Group IC</u> - Stony and rocky soils with less than 35% passing No. 4 sieve (> 65% hard, durable rock larger than No. 4 sieve).

   Type of equipment and number of passes per lift will be specified for control of compaction of these materials. Occasional in-place density tests may be required to correlate equipment performance in various materials. Such tests will require determinations of mass density.

C. <u>Coarse-Grained Soils - Group II</u>: Rocky and stony materials with moderately durable rock (hard shale, siltstone, sandstone, schist, etc.). Excavation and compacting processes, including moisture-density tests (D-698 or D-1557) change the gradation of these materials. The rock fraction is hard enough, however, to allow physical sieving of various sized fractions without further breakdown.

   Insofar as possible, laboratory testing, design values and compaction control of these materials should be based on characteristics of samples taken from test fills. The breakdown characteristics should certainly be known prior to testing and design for all moderate to high hazard or important structures involving use of these materials.

   Predictions of breakdown will be made on the basis of special laboratory tests and correlation studies when data from constructed embankments or test fills are not available. (Fig. 1 and Table 1.)

   1. <u>Sub-Group IIA</u> - 65% or more passing No. 4 sieve after compaction.

      <u>Laboratory tests and design values</u>.

      Design values will be determined by testing the minus No. 4 fraction when breakdown results in compacted material with less than 35% rock (plus No. 4) or when this high degree of breakdown is required to secure adequate strength, impermeability or other engineering properties.

      Laboratory tests will be conducted on samples processed to pass a No. 4 sieve with all particle sizes represented in the

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TABLE I - CHARACTERISTICS OF OKLAHOMA SHALES USED FOR COMPARISON OF LABORATORY BREAKDOWN TEST RESULTS AND TEST FILL 8REAKDOWN RESULTS

Sample No.	Site	Geologic Formation	Hard- ness	Free Swell %	Slaking (I hour)	Atterberg Limits (- #40)		Class	Salt	Disp	Fines G_s	8ulk Density of Rock		COMPACTION								Project Engineers Evaluation of No. 4 Separation After Compaction on Fill
														Mod. (- #4)		One Point at Mod. Effort - 6" Mold Gradation - (Before)/(After)						
64W						LL	PI					γd pcf	w %	γd	w_o %	Test.	< #4	< 3/4"	< 1-1/2"	γd	w %	
2408	Upper Clear 8oggy #24	Des Moines (Mid-Penn) Gray Mod. hard Breaks easy w/fingers	2-	30	Severe	43	22				2.74	130.0	10.0	121.0	12.5	(a)	32/58	69/95	100/100	123.3	12.5	Impossible
																(b)	32/60	97/95	100/100	122.8	12.2	
																(c)	0/61	0/97	100/100	132.2	11.0	
2409	Upper Clear 8oggy #33	Woodford (Penn) Hard, flat platy shale Brittle	3+	20	None	43	11				2.50	110.0	11.3	97.0	21.0	(a)	32/74	69/100	100/100	94.6	15.7	Possible
																(b)	32/74	69/100	100/100	95.1	15.1	
																(c)	0/57	0/95	100/100	102.0	11.7	
2410	Fourche Maline #4	Savanna Hard, soapy shale Very difficult to break with fingers	2+	20	Slight	34	13				2.76	143.0	6.6	129.0	10.5	(a)	32/53	69/86	100/100	127.5	7.2	Possible
																(b)	32/52	69/87	100/100	128.0	7.3	
																(c)	0/39	0/74	100/100	134.3	6.5	
2411	Sallisaw #11	Atoka Hard, slatey Difficult to break w/fingers	2	30	None	37	13				2.83	134.0	9.8	124.5	12.0	(a)	32/59	69/99	100/100	124.1	10.1	Difficult
																(b)	32/61	69/98	100/100	122.9	10.2	
																(c)	0/56	0/99	100/100	127.1	9.4	
2412	Boggy #28	Cloud Chief (Perm) Red-brown soft siltstone Breaks easy w/fingers	2-	0	Severe	36	15				2.72	106.0	12.7	116.5	13.5	(a)	32/77	69/100	100/100	110.8	12.6	Impossible
																(b)	32/71	69/99	100/100	109.6	13.7	
																(c)	0/82	0/95	100/100	119.6	9.1	
2413	Boggy #13	Doxey (Perm) Red-brown hard siltstone Very difficult to break	2+	20	Slight	31	9				2.75	132.0	7.6	124.0	12.5	(a)	32/63	69/95	100/100	125.3	8.6	Difficult
																(b)	32/62	69/95	100/100	124.4	8.6	
																(c)	0/54	0/92	100/100	132.1	7.8	

Comp. Test (a) Natural Moisture; Standard Gradation, 100% < 1-1/2", 69% < 3/4", 32% < #4.
Comp. Test (b) Test (a) Sample with Absorbed Water.
Comp. Test (c) Special Gradation; 100% < 1-1/2", 0% < 3/4".

mixture. Test specimens will generally be compacted to 95% of maximum density obtained by Test ASTM D-698, Method A, or 90% of maximum density obtained by Test D-1557, Method A.

Compaction requirements will generally call for Compaction Class A controlled to a specified degree of maximum density obtained by specified test method. They may also call for compacted material to have a certain breakdown as: 65% or more passing No. 4 sieve.

Field compaction control.

In-place density will be determined using Tests S-2, S-3, S-4, or S-5, NEH, Section 19, with Test S-2 generally preferred. The test sample should be separated on a No. 4 sieve. Material larger than No. 4 sieve should be cleaned as well as possible without washing (see Appendix I). The moist weight and volume of material larger than the No. 4 sieve will be determined and subtracted from the total moist weight and volume of the test sample.

Volume measurements of the rock fraction by water displacement will require soaking the rock to saturation prior to measurement if it is not already near saturation.

Volume measurements of rocks that disintegrate when soaked in water should be made by (a) substituting kerosene or diesel fuel for water as a displacement liquid in Test S-5, NEH, Section 19, or (b) determining the moist bulk density of several larger pieces of rock representing the entire rock fraction by Test S-15, Method B, NEH, Section 19.

Additional instructions for measuring the volume of moderately durable rocks are included in Appendix I.

When moist bulk density of individual rocks is used to compute the total volume of rock, it must be determined that the moisture contents are comparable for the rock in the test sample and rock used for the bulk density tests. In such cases, the total volume of rock in the sample would be computed as:
Moist weight of rock divided by moist bulk density of rock. If various kinds of rock occur in the test sample or if the moisture content of the rocks is variable, all rocks in the test sample and in the bulk density determination should be dried and the bulk density computed on the basis of dry weights.

Maximum density values to be used in computing the degree of embankment compaction should be determined by performing the specified Test D-698 or D-1557 (Method A or B) on material passing a No. 4 sieve collected from and immediately around the in-place density excavation.

2. Sub-Group IIB - 65-35% passing No. 4 sieve after compaction (35-65% moderately durable rock larger than No. 4 sieve after compaction).

Laboratory tests, design values and compaction control should be based on characteristics of materials compacted in test fills whenever possible. Proposed use of these materials in critical sections of any structure will require test fill information prior to testing and design.

The long-time weathering and stability characteristics must be considered in establishing design values and placement recommendations for all materials containing more than 35% non-durable rock.

When Class A compaction is specified, laboratory tests and construction control will be based upon mass density.

Laboratory tests and design values.

Laboratory tests and design values will be based upon maximum density of the minus No. 4 fraction adjusted for 40% plus No. 4 with varying percentages of rock. As an example, shear and permeability tests might be performed on samples of the mass passing 1-inch or 3-inch sieves and graded according to laboratory breakdown tests (Figure 1). All test specimens would be compacted to a specified base density equal to specified percentage of maximum modified (D-1557) density of the minus No. 4 fraction adjusted for 40% rock. Different amounts of rock would be added to each set of test specimens. For example: (a) the maximum modified density of the minus No. 4 fraction of a shale sample might be 105 p.c.f., (b) 90% of maximum modified γ_d = 95 p.c.f., (c) assuming a bulk density of the shale at 140 p.c.f., the adjusted γ_d of the mass with 40% rock would be 108 p.c.f., and (d) all test specimens would be compacted to a mass density of 108 p.c.f. with one set containing 35%, one set 50%, and another set 65% rock of uniform gradation between the No. 4 size and maximum size to be tested.

Field compaction control.

In-place density will generally be determined using Test S-2, NEH, Section 19, or the plastic liner method. Instructions for separating and measuring the volume of rock when size separations are required are given in Appendix I.

Compaction requirements may call for minimum mass density regardless of amount of rock or they may call for specific mass densities for varying rock contents. In the latter case, it would be necessary to determine the percentage by dry weight of plus No. 4 material for each in-place density test.

Moisture tests on these materials may require special methods discussed in Appendix I.

3. Sub-Group IIC - Less than 35% passing No. 4 sieve after compaction (>65% moderately durable rock).

   Laboratory tests and design values.

   Laboratory tests will not generally be performed on these materials. Design values will be based on results of tests on similar materials adjusted for rock contents greater than 65%, on field evaluation of actual performance in constructed fills, and on published data for large-scale field and laboratory tests.

   The long-time weathering and durability characteristics of these materials are extremely important in establishing design and placement recommendations.

   Field compaction control.

   Compaction control tests will not generally be performed on these materials and compaction requirements will be based on specification of method of placement.

D. Group III - Gravelly and stony soils containing soft, non-durable rock. The rock fractions of these materials are so soft and break down so easily that it is impossible to make a physical separation of various sizes.

Laboratory tests and construction control will be based on mass density. It is important, however, that information be submitted with laboratory samples stating that size separations will not be feasible for construction control of these materials. Unless the testing facility is informed that such separations are not possible for construction control, laboratory tests and design values might be based erroneously on size separations that cannot be made on the job.

Laboratory tests and design values.

Design values for these materials will involve a series of laboratory tests based on moisture-density relationships of material processed to pass No. 4 sieve. Individual test samples will be synthesized by the addition of varying amounts (20% to 40%) of plus No. 4 material.

Field compaction control.

Compaction requirements will call for a minimum mass density. In-place density will be determined by Tests S-2, S-3, S-4, or S-5, NEH, Section 19.

APPENDIX I [1/]

Details on Construction Control Tests for Rocky Soils in Compacted Earth Fills

Methods and equipment required for moisture-density (compaction) control tests in rocky soils vary from those ordinarily used for fine-grained soils.

Such factors as the selection and preparation of a representative test site, the dimensions of the control test hole, the type and size of equipment used to measure the volume of the test hole, sample sizes needed for moisture determinations are all affected by the amount of rock, the kind of rock (durable or non-durable), and the size of rock in the compacted embankment to be tested.

I. Test Site Selection.

The site selected for an in-place density test in rocky soils should represent average soil and rock conditions for a particular zone or lift of fill or borrow source.

A site containing occasional rocks larger than normally encountered would not be representative. Randomly occurring rocks two to three times larger than the maximum size of the major portion of embankment material being tested should generally be considered as non-representative. This is particularly true when dealing with many of the fine gravelly tills and alluviums containing less than 35 percent rock with occasional cobbles. For compacted materials with mass densities of 110 to 125 p.c.f. and rock densities of 120 to 140 p.c.f., one 5-inch diameter rock would be equivalent to about 35 percent of the total sample from a test hole 6 inches diameter x 8 inches deep. If all other rock in the sample is 2 inches or less in diameter, a 5-inch diameter rock is obviously not representative of the rock fraction. Similarly, a 2-inch rock may produce misleading results in a density test sample of material containing up to 65 percent rock which otherwise passes the 1/2 inch sieve.

When random oversize rocks are encountered in a test, a new site should be selected or the weight and volume of the oversize rock deducted from the total weight and volume of the test sample. Proper notations should be entered in the density test records when adjustments in weight and volume are made for oversize rock.

The amount of rock in a density test sample should represent average conditions. A site containing 5 percent to 10 percent rock would hardly be representative when most of the soil being used contains 25 percent to 35 percent rock.

1/ Appendix to Technical Release No. 27, dated February 4, 1965, on "Laboratory and Field Test Procedures for Control of Density and Moisture of Compacted Earth Embankments."

II. Test Hole Volume Measurements.

The size of test hole and the type of equipment used to measure the volume of material removed vary with the amount of rock and the maximum size of rock.

Table A-I, attached, shows recommended minimum volumes and dimensions of in-place density test holes for varying sizes of rocky materials. Test hole dimensions include top width, bottom width and depth. Bottom width dimensions are included since it is difficult to excavate test holes with vertical side walls in rocky soils.

Methods for measuring test hole volumes are identified in Table A-I. The Sand Cone Method (NEH, Section 19 - Test S-2) using cones 6.5 inches and 12 inches in diameter generally works well for materials with maximum size rocks up to 4 inches in diameter.

For very rocky materials with particle sizes larger than 4 inches in diameter, the pliable liner-water volume method is recommended. This method involves fitting a thin rubber or polyethylene sheet liner into the test hole and measuring the volume of water required to fill the lined hole. Plastic drop sheets classified as No. 4 and 0.004 gauge available in most paint and hardware stores work well for this test. The plastic sheets should be thin enough to conform to surface irregularities in the test hole, yet sturdy enough to resist puncture by sharp rocks.

A. Test Site Preparation and Measurement of Surface Irregularities.

Any in place density test site should be as level and smooth as practicable. Surface irregularities generally exist, however, when testing rocky soils.

1. <u>Sand Cone Method.</u>

In using a sand cone for density tests, a base plate may or may not be used. In either case, the tare weight of sand necessary to fill the cone is generally determined for each calibrated lot of sand and then used as a standard weight in subsequent tests. When surface irregularities exist at the location of the in-place density test, the standard weight of sand to fill the cone, as previously determined on a plane surface, will not be applicable. Using a <u>standard correction</u> for amount of sand to fill the cone will result in a volume less than true volume of material removed (higher density than true) when rocks extend above the surface of the plane to be excavated. A volume greater than true volume

of material removed (lower density than true) will result when holes and indentations occur on the surface of the plane to be excavated or when the base plate is not flush with the surface and sand moves into any annular space between base plate and test surface.

Whenever the surface cannot be prepared in a level plane, a test should be run on the test site before the hole is excavated to determine the amount of sand necessary to fill the cone and surface irregularities - ASTM D-1556, Note 7.

2. Plastic Liner Method.

The same potential error in volume measurements on irregular surfaces exists when using the plastic liner and water method.

The following procedure is recommended when the surface of the test location cannot be prepared in a level plane.

a. A template made of metal (preferred) or wood; square or round, and varying in size from 24 inches to 72 inches x 2 inches to 6 inches high should be firmly seated over the test location in as level position as possible. Rocks immediately under the edges of the template should be removed without disturbing the surrounding soil and discarded from the test.

b. Fit the plastic liner inside the template, taking care to eliminate all folds in the plastic, to fit it snugly into the corners of a square template and to line any cavities along the edge of the template resulting from removal of rocks in the seating process.

c. Measure and record the amount of water required to fill the template to a point of overflow or some arbitrary level measured by hook gauge or other accurate means. It is generally easier to weigh the water involved than measure volumetrically.

d. Remove the water and plastic liner and proceed with the test. At least part of the water should be removed before attempting to lift out the liner.

B. Test Hole Excavation.

Care should be exercised in excavating and preparing the hole for in-place density measurements.

The top dimension of the hole should be the same dimension as the hole in the sand cone base plate or liner template.

The sides of the hole should be as smooth as possible. Rocks and stones protruding from the sides may prevent the sand or water-filled plastic from completely filling all voids under and around the rocks. This is particularly true when the stones are flat or angular and oriented at right angles or obliquely downward to the vertical axis of the hole. In such cases, it is generally better to remove the stone from the side of the hole than to leave it in place. When a stone is removed from the side of the hole, the resultant cavity should be enlarged and flared to allow free and full occupancy by sand or liner.

The bottom of the hole should be dished or cupped as much as possible.

C. Volume Measurements.

Extreme care should be exercised in making and recording all measurements of weight and volume. Small errors in any measurement are accumulative and become significant when converted to units of pounds per cubic foot.

The procedure for measuring the volume of material removed from the density test excavation with sand cone is well covered in the Construction Handbook and in ASTM D-1556.

The procedure for the plastic liner method is as follows:

1. Seat template and liner on surface to be tested. If surface is not smooth and level, determine amount of water to fill the template to overflowing or to a predetermined level on the template.

2. Excavate hole within confines of the template - save and weigh material removed from the excavation.

3. Fit the plastic liner into the hole as snugly and evenly as possible. This can best be done by working the liner against the sides of the hole as it is filled with water.

4. Determine amount of water necessary to fill the hole and template to overflowing or to the same level as used to to determine initial tare for surface irregularities (step 1). Water measurements will generally be made in pounds (to the nearest 0.01 lb.), grams or cubic centimeters. Check the hole to be sure the plastic did not leak after emptying and removing the liner - if leaks have occurred, the volume measurement must be repeated.

5. The volume of material removed from the test hole will be equivalent to the total volume of water used to fill

the hole and template less the volume used to fill the template on the surface of the ground (tare) as:

Volume in cu.ft. = (Total pounds water - tare pounds water) x 0.01603

= (Total grams or c.c. water - tare grams or c.c. water) x 0.0000353

Other conversion factors which may be useful are:

1 gallon water @ 62° F. = 8.337 lbs.

= 0.13368 cu. ft.

= 3785.4 cu. centimeters

1 pound (avoirdupois) water = 0.01603 cu. ft.

= 453.6 grams or cu.centim.

1 cu. cent. (c.c) = 1 gram water = 0.0000353 cu. ft.

1 cu. ft. water = 62.4 lbs.

III. Screening and Separating Coarse and Fine Fractions When It Is Necessary to Determine the Amount of Rock Larger Than a No. 4 or a 3/4-inch Sieve.

Methods used to separate the fine and coarse fractions will vary with the nature of the rock.

A. Hard Rock with Low Absorption (< 5%) Capacity.

When all rock in a sample has low absorption capacity, size separations may be made by washing the entire sample on the specified sized sieve (No. 4, 3/4-inch, etc.).

Representative samples of the finer fraction should be collected for moisture determinations before the washing process.

Absorption capacities of several samples of rock should be determined prior to actual testing operations to be sure that low absorption materials are involved. Absorption capacity may be determined in the following manner:

1. Soak rock specimens in clear water for at least 24 hours.

2. Remove specimen from water and remove all surface water by blotting and patting with absorbent paper.

3. Weigh saturated, surface dry specimens.

4. Oven dry specimens to constant weight. This may require 24 hours or longer.

5. Compute percent absorption as:

$$\frac{\text{Net weight - dry weight}}{\text{Dry weight}} \times 100$$

B. Rock with Moderate to High (> 5%) Absorption Capacity (Some Hard Rock, Shale, Sandstone, Chalk, etc.) and Mixtures of Rock with Variable Absorption Capacities.

When these materials form the rock fraction of samples to be separated on the No. 4 or 3/4 inch sieve, the sample should not be washed through the separating sieve. Absorption of water by the rock during the washing process results in erroneous values for moist weight of rock.

The following methods are recommended:

1. Materials with Low Plasticity Fines (SW,SP,GW,GP,SM,GM)

   a. Determine moist weight of the total sample. Extract a representative sample of the finer fraction (minus No. 4 or minus 3/4 inch) for moisture determination. This may require preliminary screening of a portion of the sample before processing the entire sample.

   b. Sieve the total sample on the specified sieve (No. 4 or 3/4 inch) brushing and rubbing as much soil from each rock as possible.

   c. Determine the moist weight of the brushed rock.

   d. Determine the volume of brushed rock by measuring the displacement in a siphon can or graduated cylinder as described in a succeeding section.

   e. Compute the moist weight and volume of the finer fraction (minus No. 4 or minus 3/4 inch) by subtracting the moist weight of rock from the total moist weight of sample and the volume of rock from the total volume of the sample.

   f. Determine the oven dry weight of the rock if percent of rock by weight is required.

2. Materials with Plastic Fines (SC, GC).

   When it is impossible to clean the rock by rubbing and brushing, the procedure should be as follows:

a. Determine moist weight of the total sample.

b. Extract a representative sample of the finer fraction for moisture determination.

c. Screen the entire sample on the prescribed sieve rubbing and brushing as much soil as possible from the rocks.

d. Determine the moist weight of the brushed rock (plus adhering soil).

e. Wash the rock as clean as possible.

f. Determine the weight of washed rock.

g. Measure the volume of washed rock.

h. Compute the weight of moist soil adhering to the rock= [(d) - (f)]. Add this weight to the moist weight of fine fraction separated on the sieve in step (c), thus giving the total moist weight of fine fraction = [(a) - (d) + [(d) - (f)] .

i. Determine the dry weight of rock if the percentage of rock by weight is required.

Note: When large samples (12 inch sand cone or plastic liner test) are involved, it may be easier to perform the sieving operations after drying the entire sample. In such cases a representative sample of the finer fraction should be extracted for moisture determination before drying the remainder of the material.

IV. Volume Measurement of the Rock Fraction.

The following methods are recommended for measuring the volume of any portion of the rock fraction (larger than the No. 4 sieve, larger than 3/4 inch, etc.). It should be noted that rocks with moderate to high absorption (> 5%) should be saturated before volume measurements by liquid displacement are made.

A. Siphon Can or Other Overflow Volumeasure.

This method involves a direct measurement of the volume of liquid displaced through an overflow pipe when a sample is completely immersed in the measuring device.

Figure A-I-a illustrates two types of siphon cans used for displacement measurements.

The Type I device has the outlet of the siphon tube at a lower elevation than the inlet. The siphon tube drains

completely at the end of each measurement and must be re-primed for each test. When the volume of specimen to be measured is not sufficient to activate the siphon, non-absorbent articles of known volume can be introduced with the specimen. Be sure to subtract the known volume from the total volume displaced for net volume of specimen being measured.

The Type II device has the outlet end of the siphon tube at a higher elevation than the inlet end. The siphon tube retains its "prime" and does not drain out at the end of each measurement. When operating properly, this type of siphon can is very sensitive and is activated as soon as any object is inserted for measurement.

Care should be exercised in making the Type I device to be sure that (a) the end of the siphon tube placed inside the can is cut square and placed in a plane parallel with the bottom of the can; (b) the inlet end of the siphon tube is reamed and filed to a sharp edge. Correct positioning and conditioning of the inlet end of the siphon tube is less critical for the Type II can but the outlet end should be reamed and filed for this type. Small diameter tubing (< 3/8 inch i.d.) should be used for the Type II can since proper operation depends on retaining the "prime" in the siphon tube. Larger diameter tubing can be used for the Type I can. The curved section of the siphon tube for both types of can should be round with essentially the same diameter as the remainder of the tube. The baffle around the outlet of the siphon tube is particularly helpful in dampening the water turbulence caused by immersion of the specimen in the Type I can.

Siphon cans should be placed in a level position on a solid base when used for volume measurements. The action and accuracy of the device should be checked several times before use by measuring the displacement from a non-absorbent article of known volume.

The siphon can should always be filled above the siphon tube and allowed to drain before volume measurements are made.

Outlet tubes other than a siphon tube can be used to measure displaced overflow. Straight outlet tubes do have some disadvantages in that the last of the overflow may dribble out for several seconds (flow through a properly constructed siphon will stop instantly when water level in the can reaches that of the siphon inlet) and the lip of water formed by surface tension at the inlet of the tube may vary from test to test.

B. Direct Reading Volume Measurements.

The volume of liquid displaced by rock specimen can be determined by recording the water level in a cylinder or other container before and after immersing the specimen. Direct readings in cubic centimeters will be obtained by using a graduated cylinder.

Displaced volume can be measured in any container by marking the container, first, at the initial water level without specimen and, secondly, after submerging the specimen and then measuring or weighing the amount of liquid required to fill the container between the two marks. Figure A-I-b shows one method of volume measurement in an ungraduated container.

C. Volume measurements of moderately durable (Group II) rocks that disintegrate when soaked in water can be made using the siphon can or cylinder method with kerosene or diesel fuel instead of water as the displacement liquid.

D. Volume measurements of rocks or other materials (soil clods) that disintegrate when immersed in water can be made by waxing the specimen and then measuring water displacement in a siphon can or graduated cylinder as follows:

1. Clean and brush all soil and loose particles from the specimen.

2. Determine weight of each specimen (generally in grams).

3. Waterproof each specimen by carefully coating with melted wax.

   Note: Waterproof fish line or ladies' nylon hair nets may be used to make cradles for immersing the specimens in wax. High melting point wax (mixture of bees' wax and paraffin) provide a more uniform coating than ordinary paraffin. The temperature of the melted wax should be just above the melting point when the specimen is immersed. If the wax is too hot, it readily penetrates into the pores of the specimen. Two or more immersions in wax may be required to completely waterproof the specimens.

4. Weigh each waxed specimen (generally in grams).

5. Determine the volume of each waxed specimen (generally in cubic centimeters).

6. Strip the wax from each specimen and determine the moisture content.

7. Determine the specific gravity of the wax used to waterproof the specimens. This may be done by molding or trimming specimens of the wax into easily measured forms, weighing the specimens and accurately measuring the dimensions of the specimens. It may also be done by measuring the water displaced by a known weight of wax. Submerging the wax specimen for displacement measurements may be done by weighting the specimen with an impervious article of known volume.

8. Compute the volume of wax coating the specimen as: weight of wax divided by specific gravity of wax.

$$\text{Vol. wax} = \frac{\text{Wt. of waxed specimen (4) - wt. of unwaxed spec. (2)}}{G_s \text{ of wax}}$$

9. Compute the volume of test specimen as:

Vol. of rock = Total volume of waxed specimen (5) - vol. of wax (7)

10. Form SCS-543, NEH, Section 19, may be used to record data for this test.

V. Moisture Determinations.

ASTM D-1556 and NEH, Section 19, provide the following guides for minimum amounts of material required for moisture determinations:

Max. Size Particles in Total Sample	Sample Required for Moisture Grams
1/2"	250
1"	500
2"	1000

Large samples of material (50 lbs. or more) are excavated for in-place density tests on embankments with rock larger than 2 inches. Selecting a representative sample for moisture determinations on such materials is no problem if density control is based on the minus No. 4 or the minus 3/4 inch fractions. The sample is separated on the specified sieve and moisture content determined on a portion of the finer material. The moisture content of the rock larger than the density control fraction is not required when volume of oversize rock is measured.

However, selecting a portion of the total sample that will represent the moisture content of the mass is very difficult

when these large samples are involved. This is particularly true when materials contain rock of variable composition and moisture absorption characteristics.

The following alternate procedures and precautions are recommended for moisture determinations of the <u>mass</u> on materials with more than 35 percent rock with maximum sizes larger that 2 inches.

A. Drying the entire sample taken from the test excavation is the preferred method for moisture determinations. Type and size of drying equipment and time involved for testing limit the practicability of this method.

B. When drying the entire sample is not practical, the sample should be separated at some arbitrary size and moisture determined for a <u>portion</u> of the finer fraction and for a <u>portion</u> or the <u>entire</u> coarser fraction. The problem in trying to represent the moisture content of the mass by drying a portion of the total mass arises from the difficulty in splitting out a small sample that truly represents the gradation of the total sample, especially when rock sizes range from 1/4 inch up to 4 inches to 6 inches or larger. A better representation of the smaller sizes can be made by separating the sample on a 1-inch or 2-inch sieve and determining the moisture content of 500 to 1000 grams of this fraction. If the rock in the coarser fraction is uniform in composition and hardness, a portion of the coarse fraction could be used for moisture determinations. The entire coarse fraction should be dried when different kinds of rock are present in the sample.

C. More than the normal length of time will be required to dry coarse fractions with hard rocks 1 inch or larger in size and any coarse fractions containing porous shale, chalk, sandstone and the like.

VI. Example Computations.

The following simplified examples will illustrate computations of in-place density and moisture.

A. Embankment material has 35% to 50% rock (plus No. 4) with maximum size of 4 inches. Rock consists of mixed quartzite, conglomerate and hard sandstone. Specifications call for compaction control on minus 3/4-inch fraction.

Volume Determination - 12-inch sand cone

(1) Wt. of sand to fill cone (in place)	= 5.0 lbs.
(2) Wt. of sand to fill hole + cone	= 45.0 lbs.
(3) Net wt. of sand for volume measurement= (2)-(1)	= 40 lbs.
(4) Bulk density of test sand	= 100 lbs./cu.ft.
(5) Volume of test hole = (3) ÷ (4)	= 0.40 cu.ft.

Moisture-Density Determinations

(6) Total weight moist material	= 60.00 lbs.
(7) Moist wt. of +3/4" fraction	= 15.00 lbs.
(8) Volume of +3/4" fraction	= 0.10 cu.ft. (measured)
(9) Volume of -3/4" fraction = (5) - (8)	= 0.30 cu.ft.
(10) Moist wt. of -3/4" fraction = (6) - (7)	= 45.0 lbs.
(11) % Moisture of -3/4" from 500 gr. sample	= 15%
(12) Dry wt. of -3/4" fraction = $\left[(10) \div \left(1 + \frac{(11)}{100}\right)\right]$	= 39.13 lbs.
(13) γd of -3/4" fraction = (12) ÷ (9)	= 130.4 lbs/ft.^3

Note: Moisture content and dry weight of +3/4" fraction not required as specification based on -3/4" and volume of +3/4" measured.

B. Same embankment and material as Example "A" but specifications call for compaction control on mass.

Volume Determination

1, 2, 3, 4, 5 - Same as Example "A"; Volume of test hole = 0.40 cu.ft.

Moisture-Density Determinations

(6) Total moist weight	= 60.00 lbs.
(7) Moist wt. of +3/4" fraction (sample split for better representation of moisture content)	= 15.00 lbs.
(8) Volume of +3/4" fraction	= 0.10 cu.ft. (measured)

(9) Volume of -3/4" fraction = (5) - (8) = 0.30 cu.ft.

(10) Moist wt. of -3/4" fraction = (6) - (7) = 45.00 lbs.

(11) % Moisture of -3/4" fraction = 15.00% (from 500 gr.sample)

(12) Dry wt. of -3/4" fraction = $\left[(10) \div \left(1 + \frac{(11)}{100}\right)\right]$ = 39.13 lbs.

(13) Wt. dry of +3/4" fraction (Entire +3/4" fraction dried due to variance in rock) = 13.55 lbs.

(14) Total dry wt. mass = (12) + (13) = 52.68 lbs.

(15) γ_d mass = (14) ÷ (5) = 131.7 lbs./ft.^{3}

(16) % Moisture mass = $\left[[(6) - (14)] \div (14)\right] \times 100$ = 13.9%

(17) % of +3/4" material = (13) ÷ (14) x 100 = 25.7%

C. Embankment material has 35%-60% rock with maximum size of 6 inches. Rock consists of hard granite and gneiss. Specifications call for compaction control on the mass.

<u>Volume Determinations - 30" Template & Plastic Sheet</u>

(1) Wt. of water to fill template before excavation = 62.40 lbs.

(2) Wt. of water to fill template after excavation = 187.20 lbs.

(3) Net wt. water for excavation = (2) - (1) = 124.80 lbs.

(4) Vol. of excavated material = (3) ÷ 62.4 = 2.00 cu.ft.

<u>Moisture-Density Determinations</u>

(5) Total moist wt. material excavated = 303.0 lbs.

(Material separated on 1" sieve for moisture determination).

(6) Moist wt. of +1" fraction = 116.50 lbs.

(7) Moist wt. of -1" fraction = (5) - (6) = 186.50 lbs.

(8) Moist wt. of portion of +1" fraction (sample can be split due to uniformity of rock) = 10.00 lbs.

(9) Dry wt. of portion of +1" fraction = 9.61 lbs.

(10) % Moisture of +1" fraction = $\left[[(8) - (9)] \div (9)\right] \times 100$ = 4.05%

(11) Dry wt. of total +1" fraction =

$$\left[(6) \div \left(1 + \frac{(10)}{100}\right)\right] = 111.96 \text{ lbs.}$$

(12) Moist wt. of portion of -1" fraction (sample split) = 5.52 lbs.

(13) Dry wt. of portion of -1" fraction = 5.16 lbs.

(14) % Moisture of -1" fraction =

$$\left[(12) - (13)\right] \div (13) \times 100 = 7.00\%$$

(15) Dry wt. of total -1" fraction =

$$\left[(7) \div \left(1 + \frac{(14)}{100}\right)\right] = 174.30 \text{ lbs.}$$

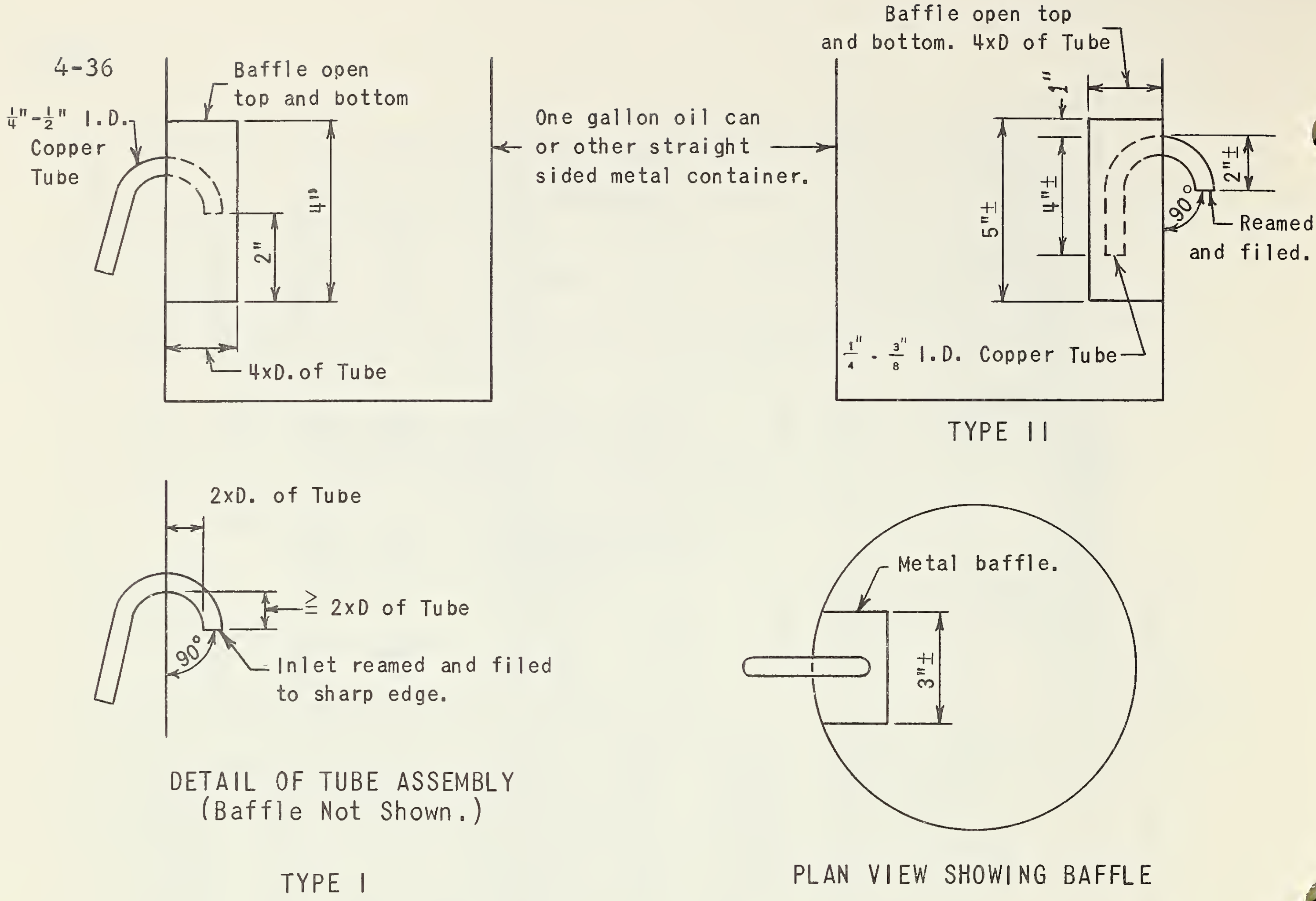
(16) Total dry wt. = (11) + (15) = 286.26 lbs.

(17) γ_d mass (total) = (16) ÷ (4) = 143.1 lbs./ft.

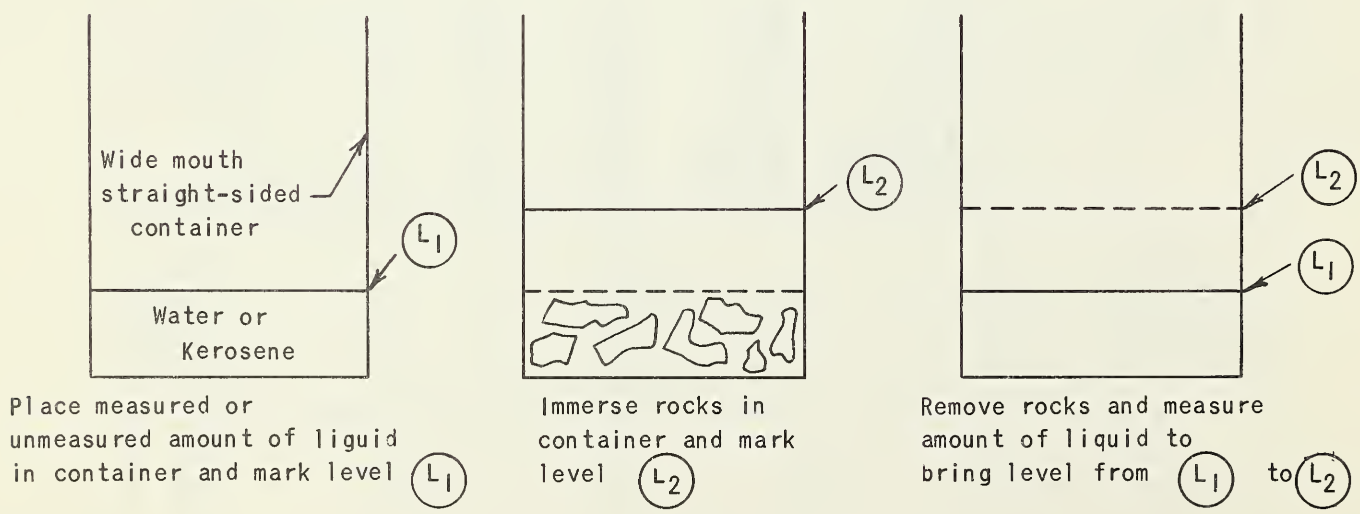
(18) % Moisture of mass = $\left[\left[(5)-(16)\right] \div (16)\right] \times 100 = 5.9\%$

Table A-I - In-place density test specifications

Soil Group	% Rock (+ No. 4)	Maximum Particle Size in Mass Diameter	Compaction Control	In-Place Density Tests: Method	Test Hole Volume Cu. Ft.	Test Hole Dimensions: Top In.	Bottom In.	Depth In.
IA IIA	< 35	2"	- No. 4	$6\frac{1}{2}$" sand cone	0.10	6.5	4	8
		2" - 4"	- No. 4	12" sand cone	0.40	12	8	12
IB IIB	35 - 65	2"	Group IB generally controlled on -3/4" or mass	$6\frac{1}{2}$" sand cone	0.10	6.5	4	8
		2" - 4"		12" sand cone 12" template & plastic liner	0.40	12	8	12
		4" - 6"	Group IIB generally controlled on mass	24" to 30" template with plastic liner	1.00 to 2.00	24 to 30	12 to 18	12
		6" - 12"		48" template w/ plastic liner	10.00 to 14.00	48	24	18
IC IIC	> 65	4"	Mass & Method	12" sand cone 12" template w/ plastic liner	0.20 to 0.40	12	Variable	12
		6"	Mass & Method	30" template w/ plastic liner	1.00 to 2.00	30	Variable	12
		12"	Mass & Method	48" template w/ plastic liner	10.00 to 14.00	48	Variable	18
		15"	Mass & Method	72" template w/ plastic liner	15.0 to 18.0	72	Variable	18
III	5 - 65	Indeterminate	Mass	$6\frac{1}{2}$" sand cone	0.10	6.5	4	8



a. SIPHON CAN FOR MEASUREMENT OF VOLUME BY DISPLACEMENT.



NOTE: If initial amount of liquid is measured into container as V_1, only the final level, L_2, need be marked; then volume of solids V_s = VOLUME REQUIRED TO FILL TO LEVEL L_2 MINUS V_1.

b. MEASUREMENT OF DISPLACEMENT IN UN-GRADUATED CYLINDER.

Figure A-1: Methods of measuring volume of solids by water displacement.

Report Forms for Embankment Moisture, Volume & Density Determinations SCS-530A and SCS-530B

Instructions For Use.

Form SCS-530A (Rev.), "In Place Moisture-Density Determinations," Figure 4-4, 4-4 (back), has been prepared for use in recording moisture, volume and density test data for fine grained and gravelly soils that are tested on the material passing the No. 4 sieve.

Form SCS-530B (New) "In Place Moisture-Density Determinations," Figures 4-5, 4-5 (back), has been prepared for use in recording moisture, volume and density test data for gravelly and rocky soils, tested on fractions larger than No. 4 sieve size or on total material (mass).

It is proposed that these two forms will suffice for field use when testing density by the: Sand Cone Method, Test S-2, Rubber Balloon Method, Test S-3, Calibrated Cylinder Method, Test S-4, Kerosene Method, Test S-5, or by additional test methods which may require open test pits or other special procedure.

Each test should be carefully documented as required to make a complete record at the time of actually performing the test. Any deviation from standard procedure or test results that are recognized as irregular or unusual should be explained or noted in the remarks section of the form. Each test should be numbered in consecutive order. A predetermined letter or abbreviation is desirable as a prefix to the number, to identify the project or site. Test reports should be filed in the construction office, with special attention to determine that a complete record is maintained.

IN PLACE MOISTURE-DENSITY DETERMINATIONS
Fine Grained and Gravelly Soils Tested on Material Passing No. 4 Sieve

Location ______________________ Date ____________

Watershed ______________ Subwatershed ______________

Contract No. ____________ Contractor ______________

Site No. ____________ Sampled By ______________

Test No.	Location of Test		Borrow Source and Kind of Material
	Station and Offset	Elevation	

Test No.	Specification Requirements		Test Results		Curve No.
	Moist Range	% Compaction	% Moisture	% Compaction	

Remarks: ____

Figure 4-4

IN PLACE MOISTURE-DENSITY DETERMINATIONS FOR FINE GRAINED SOILS OR SOILS WITH ROCK THAT CAN BE SEPARATED ON NO. 4

MOISTURE DETERMINATION	Test Number			
(1) Wt. Container				
(2) Wt. Container + Moist Soil				
(3) Wt. Container + Dry Soil				
(4) Wt. of Moisture (2) - (3)				
(5) Wt. of Dry Soil (3) - (1)				
(6) % Moisture in Soil [(4) ÷ (5)] x 100				
(7) Correction for Ignition				
(8) % Corrected Moisture in Soil (6) - (7)				
VOLUME DETERMINATIONS				
[Sand-Funnel Method] (9) Wt. Sand, Cone + Container				
(10) Wt. Sand Remaining, Cone + Container				
(11) Wt. Sand Used (9) - (10)				
(12) Wt. Sand to Fill Cone and Plate				
(13) Wt. Sand to Fill Hole (11) - (12)				
(14) Bulk Density Testing Sand				
(15) Volume of Hole (13) ÷ (14)				
[Rubber Balloon Method] (16) Final Base Reading				
(17) Initial Base Reading				
(18) Volume of Hole (16) - (17)				
[Calibrated Cylinder Method]				
(19) Vol. of Cylinder = Vol. of Sample				
DENSITY DETERMINATION				
(20) Wt. Moist Sample + Container				
(21) Wt. Container				
(22) Wt. Moist Sample (20) - (21)				
(23) Wt. Moist Rock				
(24) Wt. Moist Soil (22) - (23) (1/ In grams)				
(25) Density Moist Rock				
(26) Vol. of Rock - Measured or (23) ÷ (25)				
(27) Vol. of Soil = (15)-(26) or (18)-(26) or (19)-(26) (1/ In cc.)				
(28) Wt. Dry Soil = (24) ÷ [1 + (8)/100] *				
(29) Dry Density Soil (28) ÷ (27)				
(30) Maximum γd				
(31) % Max. γd = [(29) ÷ (30)] x 100				

Remarks: ______________________________

(1/ Density-Kerosene Method Test S-5)
*[1 + (8)/100] is the number 1 and not (1) in these computations.

Computed by ______________ Date ________

Checked by ______________ Date ________

Figure 4-4 (Cont.)

IN PLACE MOISTURE-DENSITY DETERMINATIONS
Gravelly and Rocky Soils Tested on Fractions Larger Than
No. 4 Sieve Size or on Total Material (Mass)

Location ______________________________ Date ______________

Watershed ____________________ Subwatershed ________________

Contract No. ______________ Contractor ______________________

Site No. ________________ Sampled by _______________________

Test No.	Location of Test		Borrow Source and Kind of Material
	Station and Offset	Elevation	

Test No.	Specification Requirements		Test Results		Curve No.
	Moist Range	% Compaction	% Moisture	% Compaction	

Remarks: ____

____

____

____

____

____

____

Figure 4-5

IN PLACE MOISTURE-DENSITY DETERMINATION FOR GRAVELLY SOILS
TO BE SEPARATED ON SIEVES LARGER THAN NO. 4 OR FOR MASS (TOTAL) DENSITY

VOLUME DETERMINATIONS	Test Number			
[Sand Cone Method]				
(1) Wt. of Sand, Cone + Container				
(2) Wt. Sand Remaining, Cone + Container				
(3) Wt. Sand Used (1) - (2)				
(4) Wt. Sand to Fill Cone and Plate				
(5) Wt. Sand to Fill Hole (3) - (4)				
(6) Bulk Density of Testing Sand				
(7) Volume of Hole (5) + (6)				
[Plastic Liner - Water Method]				
(8) Wt. Water to Fill Hole - lbs.				
(9) Vol. Hole = (8) + 62.4				
[Calibrated Cylinder Method (Soft Plastic Shales)]				
(10) Vol. of Cylinder = Vol. of Sample				
MOISTURE-DENSITY DETERMINATIONS				
(11) Wt. Moist Sample (Total) + Container				
(12) Wt. Container				
(13) Wt. Moist Sample (Total) (11) - (12)				
(14) Moist Wt. Coarser Fraction (If Separated)				
(15) Moist Density Coarse				
(16) Vol. of Coarse = Measured or (14)+(15)				
(17) Vol. of Fine or Mass (7) - (16) or (9) - (16) or (10) - (16)				
(18) Wt. of Container for Coarser Fraction				
(19) Wt. Moist Coarse + Can (Total or Split)				
(20) Wt. Dry Coarse + Can (Total or Split)				
(21) Wt. Dry Coarse (Total or Split)				
(22) % Moisture in Coarse (19) - (20) ÷ (21) (Total or Split)				
(23) Wt. of Container for Fine or Mass				
(24) Wt. Moist Fine or Mass + Container (Total or Split)				
(25) Wt. Dry Fine or Mass + Container (Total or Split)				
(26) Wt. Dry Fine or Mass (Total or Split)				
(27) % Moisture Fine or Mass (24)-(25)÷(26)				
(28) Total Dry Wt. Fine or Mass = (26) or (13) - (14) ÷ [1 + (27)/100]*				
(29) Total Dry Wt. Coarse + Fine = (21)+(26) or (28) + [(14) ÷ [1 + (22)/100]]				
(30) Dry Density Fine or Mass (28) + (17) or (29) ÷ (7),(9) or (10)				
(31) Max. Density Fine or Mass				
(32) % Max. γd Fine or Mass = (29) + (30)				
(33) % Moisture Coarse + Fine = $\frac{(13)-(29)}{(29)}$ x 100				

Remarks: ____________________

____

____

____

* [1 + (27)/100] is the number 1 and not (1) in these computations.

Computed by ____________________ Date __________

Checked by ____________________ Date __________

Figure 4-5 (Cont.)

Embankment Construction Report (SCS 530C)

Instructions for Use.

Form SCS 530C (New), "Embankment Construction Report," Figure 4-6, 4-6 (back), should be completed for each individual embankment project to supplement the moisture-density test data determined for the site.

A minimum of descriptive detail will be required when fine grained non-gravelly soils are involved. The normal report for projects using these soils would contain brief descriptions of the placing and watering operations with descriptions of the compaction equipment, number of passes and lift thickness before and after compaction. Descriptions of materials would be brief showing classification, origin of materials, i.e. loess, till alluvium; and any other characteristics peculiar to the job.

A complete, descriptive record is desirable for projects using gravelly and stony soils or degradable shale, sandstone, siltstone, disintegrating gneiss and schist or other similar materials. It is important to evaluate methods and equipment performance in ripping and excavating these materials. All operations and equipment used to obtain the specified results should be described in detail for each type of material. Also, the descriptions of each type of material should be as complete as possible. Adequate gradation determinations should be made before and after compaction to provide a fair evaluation of equipment and methods required to obtain the specified results for each type of material.

Data recorded under "Borrow Source" and "In Place Density Test Numbers," should conform to those reported individually on SCS 530A or 530B. The in place density tests, identified by the proper number, should be grouped to represent each source of borrow material and also for each change in equipment or method used for compaction, as: borrow source - emergency spillway, Group II-B, Test Numbers H-3, 5, 9, and 15; borrow source - Borrow Area B, Group III, Test Numbers H-4, 7, 10 and 19.

This construction record form will be especially useful in evaluating test fills wherein individual density tests may be compared to specific equipment, methods and materials, including gradation characteristics.

Form SCS 530C should be used concurrently with SCS 530A or B so that a complete record of the placement and compaction results can be related to changes in material, equipment or methods.

Information recorded on Form SCS 530C combined with 530A or B will be evaluated by the State Conservation Engineers, E&WP Unit Staffs and the Soil Mechanics Laboratory Materials Testing Sections to

establish criteria for testing, preparing construction specifications and for construction control of all questionable materials, specifically those containing gravel and rock, having either durable or degradable characteristics.

SCS-530C (FRONT)
(REV. 11-19-64)

EMBANKMENT CONSTRUCTION REPORT

Watershed ______________ Sub-Watershed ______________ Site No. ______

Contract No. ________ Contractor ____________ Prepared by ______________ Date ______

I. Description of Equipment

Borrow Source	Equipment for Processing and Excavating Borrow	Equipment for Processing on the Fill (Raking, Grading, Discing, Etc.)	Compaction Equipment Type, Total Wt., Avg. Pressure Roller Dimensions, No. and Area of Tamping Feet or Tires

II. Description of Material Processing and Compaction Operations

Borrow Source	In Place Density Test Numbers	Methods and Equipment Performance in Borrow	Placement and Compaction on Fill: Equipment, No. of Passes, Sequence of Operations, Lift Thickness Before and After Treatment, Etc.

Figure 4-6

EMBANKMENT CONSTRUCTION REPORT

III. Description of Materials

Borrow Source	Lab. Sample Nos.	In Place Density Test Nos.	U. S. Class.	Group i. e. IA, III	Geologic Form and Description	Gravel and Rock		Average Gradation for Each Borrow Group and In Place Tests for Specific Processing and Compaction Operations	
						Hard-ness	Bulk Density	As Dumped on Fill % Passing Max. Size 6", 3", $1\frac{1}{2}$", $\frac{3}{4}$", #4	After Compaction % Passing Max. Size 6", 3", $1\frac{1}{2}$", $\frac{3}{4}$", #4

Figure 4-6 (Cont.)

Test No. S-2

Field Density Test - Sand Cone Method

General.

The Standard Specifications of the Soil Conservation Service require that earth fills be placed with densities which will meet the requirements for the class of fill specified in the contract. These requirements are based on the maximum density obtainable for the soil fraction as determined by a specified test procedure. Unless otherwise noted, the soil fraction is that portion of the material which will pass a No. 4 sieve. The specifications may also provide for the allowable range of moisture content for the soil fraction. During the construction of earth fills, field tests of the soil are made to determine the actual densities and moisture content being obtained in the materials being placed. One method which has been used extensively in performing this test is the sand cone method. This test method, in somewhat modified form, is covered by ASTM Designation: D 1556-58T.

Density Apparatus.

The following equipment is required for the test:

1. Steel plate 12" x 12" x 3/8" with 4" or 6-1/2" hole in center. Plates with larger center holes are available for use where larger samples are needed for testing gravelly soils.

2. Sand cone that will fit a Mason jar or larger container and will fit over the hole in the steel plate with a valve for stopping the sand flow. (Larger type sand cones can be obtained, if required to test soils, containing coarse particles.)

3. Balance of 25 pound capacity, sensitive to 0.01 pound.

4. Balance of 1000 gram capacity, sensitive to 0.1 gram.

5. Stove or oven or other suitable equipment for drying moisture samples.

6. Suitable containers with airtight lids (metal preferred).

7. Compaction mold or other volume measure.

8. Small pick, chisel, auger, or spoon for digging test holes; 10 inch frying pan or any suitable container for drying moisture samples; buckets with lids, seamless tin cans with lids, or other suitable containers for retaining the density sample, moisture sample and density sand.

9. Equipment to measure the volume of oversize material when gravel and rock particles larger than specified for density control are involved.

An array of equipment normally used in the test is shown in Figure 4-7A.

Testing Sand.
The sand used to determine the volume of the test hole should be a clean, dry, free flowing, uncemented sand passing the No. 10 sieve and retained on the No. 200 sieve (often clean "blow sand" or "dune" sand is suitable for this purpose). In selecting a sand for use, several bulk density determinations, as hereafter explained, should be made using the same representative sample for each determination. To be acceptable, the sand should not have a variation in bulk density greater than one percent.

(Note: When large sand cone equipment is used in testing gravelly soils and there are appreciable voids between the particles, coarse sand having rounded particles and passing the No. 4 and retained on the No. 8 sieve is recommended.)

Test Procedure.
Listed below is the step-by-step sequence which will normally be followed in performing the test. Refer to the reverse side of SCS-530A (Figure 4-4) for the items listed.

(1) Bulk Density of Testing Sand - In order to determine the weight of a cubic foot of sand, the container is filled with the testing sand and the density cone screwed on; this is then weighed (see Figure 4-7B) and the weight recorded. The weight of sand necessary to fill the cone is determined by placing the jar and cone on a flat surface and the sand allowed to run into the cone from the jar. When the cone is filled, the cone, jar, and remaining sand are weighed (see Figure 4-7D) and the difference between the original weight and the final weight is the weight of sand necessary to fill the cone. The next step is to again fill the jar with sand; attach the cone and weigh. Then place the cone and jar over and flush with the top of the compaction mold and fill the mold and cone with sand (see Figure 4-8A). Weigh the retained sand. The difference between the original weight and the final weight is the weight of sand used in the cone and mold. Subtract the previously determined weight of sand in cone and the remainder is the weight of sand in mold (or weight of 1/30 cubic foot of sand). Multiply by 30[1/] and this will be the bulk density of one cubic foot of the sand. Repeat several times (a minimum of three), average the results, and record as Item (14), SCS-530A or Item (6) SCS-530B, (see Figures 4-4 or 4-5).

The procedure described above is applicable when a 4 inch diameter cone is used. When using the 6-1/2 inch diameter cone the calibration of sand procedure may be modified as follows: (1) Weigh empty compaction mold; (2) Fill compaction mold with sand from

1/ If a different size mold or volume measure is used, substitute the correct conversion figure.

container and cone. Hold jar vertically inverted so that sand falls about 4 inches; (3) Strike off surface with a straight-edge, being careful not to jar the mold or vibrate the sand. Carefully sweep off all waste sand; (4) Weigh mold and sand. Weight of mold and sand minus weight of mold equals weight of 1/30 1/ cubic foot of sand; (5) Repeat several times (a minimum of three) and average the results.

(2) Weight of Sand to Fill Cone and Plate.- The weight of sand necessary to fill cone and plate is determined by inverting weighed jar of sand and cone over the plate, which has been placed on a smooth surface, and the cone and plate filled, (see Figure 4-7C). The difference between the original weight of jar, cone and sand, and the weight of the jar, cone and remaining sand is the weight of the sand used in the cone and plate. This weight is recorded as Item (12), SCS-530A, or Item (4) SCS-530B, Figures 4-4 or 4-5.

(3) Weight of Sand, Cone and Container.- The weight is determined by weighing the jar of sand and cone as explained above and is recorded as Item (9), SCS-530A, or Item (1) SCS-530B.

(4) Weight of Container.- The weight of the container for the density sample is determined and entered as Item (21), SCS-530A, or Item (12) SCS-530B.

(5) Weight of Moist Sample and Container.- At the location of the test, all loose soil to a depth not less than 6 inches below surface of lift should be removed from an area 18 to 24 inches square, and the area leveled until a firm smooth surface is exposed. The folume of the test hole is determined in accordance with the following methods:

Maximum Particle Size of Material to be Tested	Minimum Test Hole Volume, Cu. Feet
No. 4 Sieve	0.025
1/2 inch	0.050
1 inch	0.075
2 inch	0.100
4 inch	0.750

The plate with the proper size hole is selected and placed firmly on the test area, and a hole slightly smaller than the hole in the plate is dug sufficiently deep to produce the minimum required sample.

1/ If a different size mold or volume measure is used, substitute the correct conversion figure.

This may be done with hand tools, or a soil auger may be used when gravel is not present (see Figure 4-8B). While excavating, extreme care should be exercised to avoid deforming the hole; the movement of heavy equipment in the immediate test area should not be permitted.

The excavation is continued to the required depth and the hole carefully trimmed by hand to the required size and shape to remove any material that has been loosened by the excavating tools. All material removed from the hole should be placed in an airtight container for subsequent weighing. To avoid undue moisture loss, the cover should be kept on the container at all times when soil is not being placed in it. The weight of the moist soil and container is determined to the nearest 0.01 pound and recorded as Item (20), SCS-530A or Item (11) SCS-530B, (see Figure 4-8D). The weight of moist soil is computed as Item (22) SCS-530A, or Item (13) SCS-530B.

(6) <u>Weight of Sand Remaining, Cone and Container</u> - The weighed jar of sand, cone and container is then carefully placed on the plate, the valve opened, and the sand allowed to fill the hole, cone and plate (see Figure 4-5C). The valve is then closed, the remaining sand, cone and container are weighed to the nearest 0.01 pound and the weight is recorded as Item (10), SCS-530A, or Item (2) SCS-530B.

Note: The sand in the hole on occasion may be salvaged for re-use, but before the sand is re-used its bulk density should be redetermined as explained. It may be necessary to wash and sieve this sand before it will meet the requirements for testing. It is common practice to disregard the salvage of the sand and use fresh material for each test.

(7) <u>Items (11), (13), (15), and (18), SCS-530A, or (3), (5), and (7) SCS-530B</u> - are determined as shown.

<u>Note</u>: At this point the test procedure will vary according to the amount and durability of gravel or rock in the sample being tested and the test procedure specified in the Contract.

<u>Alternate A</u>
Use Form SCS-530A, for fine-grained soils or soils with rock that can be <u>separated on the No. 4 sieve without degradation</u>, and proceed as follows:

(8) <u>Weight of Container</u> - After the moist weight of the sample has been determined, a sample of the material passing the No. 4 sieve is selected for moisture determination. The weight of the container for the sample is determined in grams and entered as Item (1), SCS-530A.

(9) <u>Weight of Moist Sample and Container</u> - The volume of the moisture sample is as follows:

Maximum Particle Size In Density Sample	Minimum Moisture Samples in Grams
No. 4 Sieve	100
1/2 inch	250
1 inch	500
2 inch	1000

The moisture sample is placed in the weighed container and the weight of the sample and container is entered as Item (2), SCS-530A.

(10) Weight of Container and Dry Sample - The moisture sample is dried to a constant weight as hereinafter explained in Test No. S-10 and the weight of dry sample and container is determined and entered as Item (3), SCS-530A.

(11) Items (4), (5), and (8), SCS-530A - Values for these items are determined as shown.

(12) Weight of Moist Rock in Soil - After the moist weight of the total sample has been determined and recorded, and a sample for moisture determination has been removed, the remainder of the soil is separated into the plus No. 4 fraction (rock) and the minus No. 4 fraction (soil) by using a No. 4 sieve. The fraction retained on the No. 4 sieve (rock) is cleaned (do not wash) and weighed and the weight is recorded as Item (23), SCS-530A. The above procedure may prove difficult to perform where the soil fraction contains fines with medium to high plasticity. For material of this type two alternative methods are appliable. Alternate (1) Dry all the material before separating on the No. 4 sieve. After separation is complete, (it may be necessary to wash the rock to remove the fine particles) then dry and weigh the rock. In this case, the dry weight of the rock is determined. The moisture content of the rock is also required, this may be determined by obtaining a representative sample of rocks from the test material; thoroughly cleaning (do not wash) the rocks and determining the moisture content as outlined in the oven method, Test No. S-10. The moist weight of rock in the density sample is then computed as:

$$\text{Weight of dry rock x} \left[1 + \frac{\text{\% moisture in rock}}{100}\right]$$

The moist weight of rock is then entered as Item (23) SCS-530A.

Once the moisture content of a sample of rock has been determined, the same value may be used in subsequent tests where there is no change in material being tested.

When modified procedures are used for plastic soils, proper notes and data should be recorded in the "Remarks" space of SCS-530A. Alternate (2)(a) Determine moist weight of brushed rock (plus adhering soil); (b) wash the rock as clean as possible; (c) determine weight of washed rock; (d) measure volume of washed rock; (e) add the weight of moist soil adhering to the rock [(a)-(c)] to the total moist weight of the soil (<No. 4) fraction.

(13) Moist Density or Bulk Density of Rock and Volume of Rock - Items (25) and (26), SCS-530A. The moist density of rock is the moist weight per cubic foot of rock found in the material being tested. This value may be used to compute volume of rock as shown in Item (26), SCS-530A, under the following conditions:

It is generally desirable and preferable to determine the total volume of rock directly rather than compute the volume from average values of bulk density determined for a few rock particles.

Direct determination of rock volume can be made by measuring the water displaced when the rock is placed in a full siphon can, a graduated cylinder, or by weight in air and in water as outlined in Test No. S-15.

Direct measurement of rock volume can be done very quickly when hard, non-absorbing rock is involved. When hard shale, sandstone, or other porous absorbing rock are involved, the rock sample should be allowed to soak until completely saturated before displacement and volume measurements are made. A soaking period of one hour is generally adequate. Samples can be soaked in the siphon can, if such is used for volume measurement.

Often rock materials are encountered in tests that can be separated on the No. 4 sieve in a moist state without degrading, but soften and disintegrate or degrade when immersed in water. When materials of this nature are encountered selected pieces, three or four at least 2" x 2" x 2" in size when possible, should be waterproofed by coating with wax before measuring water displacement according to Test No. S-15, part B. Procedures for determining the bulk specific gravity or bulk density are also outlined in Test S-15. Values for rock density given in test reports may be used for computing volume of rock if materials tested in the laboratory are the same in composition and moisture content as those involved in the density test.

(14) Maximum Dry Density of Soil - Item (30), SCS-530A. This is the maximum dry unit weight obtained by running the specified moisture-density (compaction) test on material tested in the embankment. This value may be obtained from laboratory reports if materials tested in the embankment are the same as those tested in the laboratory.

(15) Values for Items (27),(28),(29) and (31), SCS-530A, - are determined as shown.

Note: Values for Items (8) and (31) should be entered in the appropriate space on the front of SCS-530A.

Alternate B

Use Form SCS-530B, for rocky soils to be separated on sieves larger than No. 4 or for determining mass (total) density.

This procedure will be used when specifications require compaction control on a fraction of the material larger than No. 4 sieve - as the minus 3/4 inch fraction - or control of moisture-density of the mass or total material.

The procedure for Items (1) through (7) are the same as given for Form SCS-530A preceding Alternate A.

Procedures for completing other items on Form SCS-530B are as follows:

Item (14) Separation of Coarser and Finer Fractions: SCS-530B. After the total volume and the moist weight have been determined for the sample - Items (7), (9), or (10) and (11), (12), (13), SCS-530B - the moist sample will be separated into two parts (coarse and fine) by screening on the appropriate sized sieve if such is specified. The terms "coarse" and "fine" in this procedure do not necessarily refer to larger than No. 4 or smaller than No. 200 sieves.

Even though a size separation is not specified for compaction control, it may be desirable to separate the sample on some arbitrary size in order to take representative samples for moisture determinations. It is difficult, for example, to take a portion of the total material that will represent the true moisture content of a gravelly material that contains several particles from 1/2 inch to 1-1/2 inch in size with moisture contents of 5 percent to 10 percent and the remaining portion dominantly finer than No. 200 sieve with moisture content of 15 percent to 20 percent. Varying the number of coarse particles in the sub-sample will significantly affect the moisture results as interpreted for the entire sample.

The most accurate determinations of moisture for mixed fine and coarse soils are those in which the entire sample of any sized separate is dried. This is not practical when large volumes of soil are involved. Larger than normal samples should be tested for moisture content when the entire sample cannot be dried.

Arbitrary size separations made to better represent moisture content should be selected so that the finer fraction is fairly evenly graded from coarsest size to the No. 4 size.

Data on particle size separations made according to specifications or arbitrarily for moisture samples should be recorded under "Remarks" on Form SCS-530B.

Items (15), (16) - Moist Density and Volume of Coarse Rock - When specific particle size separations are required - as control on minus 3/4 inch - moist density or direct volume determinations must be made for the coarser fraction. These determinations should be made according to instruction No. 13 for Alternate A, Form SCS-530A.

Determinations for moist density or volume of the coarser fraction are not required when construction control is based upon characteristics of the total material (mass density) or when arbitrary particle size separations are made to secure better sample representation for moisture determinations.

Item (17) - Volume of Finer or Mass - is determined as shown. When particle size separations are not required, this value will be for the total sample (mass).

Items (18), (19), (20), (21) and (22) - Moist - Dry Weight & Percent Moisture of coarser Fraction - are determined as shown for the entire fraction or for a portion (split) of the coarser material. Determination of these values are not required when:

(a) A separation of finer and coarser is specified (minus 3/4 inch density). The volume, Item (16) of SCS-530B, of the coarser fraction is all that is required in this case.

(b) Total or mass density is required and no particle size separations are required for moisture determinations.

Items (23), (24), (25), (26), (27) - Moist-Dry Weight and Percent Moisture of the Finer Fraction or the Mass - are determined as shown for the entire fraction or for a portion (split) of the finer fraction.

These values are determined for all tests with values representing the entire mass when particle size separations are not made for moisture determinations.

Item (28) - Total Dry Weight of Finer Fraction or the Mass - is determined as shown. If moisture was determined on the entire sample, the value entered is the same as Item (26). If the total sample was separated into coarse and fine or if the moisture of the finer fraction was determined on a portion of the total fine material, the value is calculated by computing the moist weight of the total fine fraction, Items (13) - (14), and dividing by the moisture content of the fines, Item (27).

Item (29) - Total Dry Weight of Coarser and Finer Fraction or Mass When Fractionated - It is necessary to determine this value when individual moisture tests are made on coarse and fine fractions. This value is not needed when:

(a) Specifications require density and moisture of the finer fraction only.

(b) Moisture tests are made on the entire or portions of the entire test sample without separating particle sizes.

When samples of coarse and fine are not split for moisture tests, the value is Items (21) + (26). When moisture was determined on portions of the coarse and fine, the value is computed as the sum of the total dry finer and total moist coarser corrected for moisture content as Items (28) + [(14) ÷ [1 + 22/100]].

Item (30) - <u>Dry Density of the Finer Fraction or of the Total Mass</u> - is computed as shown. Dry density of the finer fraction or of the mass without particle size separation is computed as Items (28) ÷ (17). When size separations have been made, the value is computed as total dry weight divided by total volume of sample: Items (29) ÷ (7), (9) or (10).

Item (31) - <u>Maximum Density of Fine Fraction or Total Mass</u> - is the maximum dry unit weight value determined by the specified moisture-density test procedure on material tested on the embankment or on similar material tested in the laboratory.

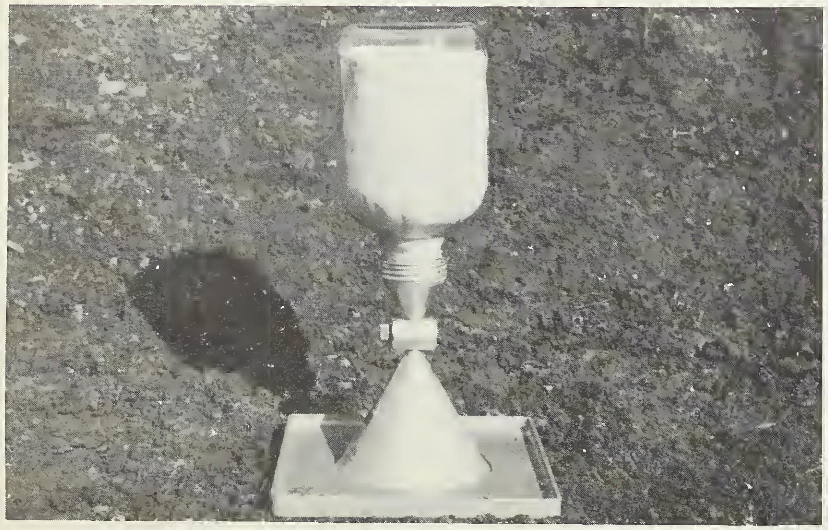
Item (32) - <u>Percent Maximum Density</u> - is computed as shown.

Item (33) - <u>Percent Moisture of the Total Sample (mass) When It Has Been Separated Into Particle Size Fractions</u> - is computed as shown. This determination is necessary when the value for moisture content of the mass is required and these tests are performed on individual sized fractions. It is <u>not</u> needed when moisture content of the finer fraction alone is required or when moisture tests are run on the entire, or portions of the entire sample without size separations.

<u>Precautions.</u>
It is very important that the valve on the cone operates freely and without any constriction when in the open position. Any reduction in the valve opening will cause the sand to flow more slowly, thus providing more opportunity for it to roll into a more dense position. Considerable care must be exercised when calibrating the sand to avoid jarring which might consolidate the sand in the jar or mold. Also in making the field density determinations, heavy equipment should not be permitted to operate in close proximity to the test. Vibrations set up by the equipment may densify the sand in the test hole, resulting in erroneous measurements.

A. - Array of equipment for Calibrated Sand Test

B. - Weighing Filled Jar of Sand and Cone



C. - Determining Sand to Fill Cone

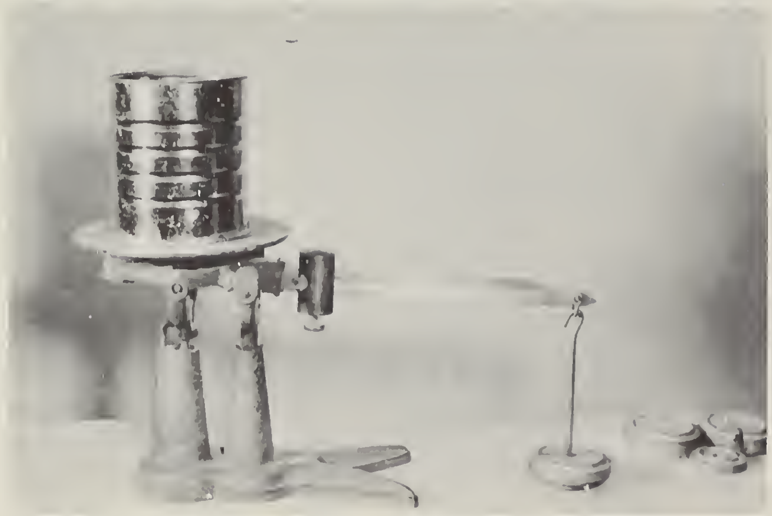
D. - Weighing Remaining Sand

Figure 4-7

A. - Determining Sand to Fill Mold

B. - Removing Field Sample

C. - Determining Size of Hole



D. - Weighing Field Sample in Can

Figure 4-8

Test No. S-3

Field Density Test - Rubber Balloon Method

General.

For the rubber balloon method of testing the in-place density of soil, a liquid is used to measure the volume of the hole. This method of determining in-place density provides an acceptable and rapid measurement of volume. However, there are some limitations to the use of this equipment; (1) Soil containing sharp angular stones may puncture the rubber membrane making its use impractical under such conditions, and (2) Accuracy of results are uncertain in coarse grained soils, thus limiting its use to the finer grained soils.

Apparatus.

Several models using the water filled balloon principal are available. This equipment is manufactured in different capacities to test soils having a range in particle size. For coarse grain soils the units having larger volumes are recommended to improve the accuracy of the test. The model or size selected for use should have the capacity necessary to determine the volume of a hole which will meet the criteria specified in the sand cone method. The model illustrated in Figure 4-9, known as the "Volumeasure" contains the following essential features:

1. A heavy wall glass cylinder, calibrated with direct reading scale etched on the cylinder wall. Capacity 1/20 cubic foot with minimum gradation of 0.00025 cubic foot. Protected by metal guard with carrying handle. Water is generally used in the cylinder as the operating fluid.

2. Separate base plate to facilitate digging operations without loss of soil sample.

3. Balloon molded of resilient latex with integral retaining collar.

4. Actuator bulb, double-acting type for pressure or vacuum, fitted with adapter, quick coupler and valve assembly attached to the base of the glass cylinder assembly.

Test Procedure.

The following procedure is followed in performing the test:

1. Place the base plate on a leveled surface where the field density measurement is to be made. (Remove loose top surface to about 6 inch depth).

2. Set the "Volumeasure" in the recess of the base plate. Open the control valve and pump the balloon down until the water level in the graduated cylinder reaches its lowest point. It is necessary to hold the equipment down during the pumping operation to insure that it remains in close contact with the subgrade (see Figure 4-9B). (This operation should be repeated

two or more times to verify the accuracy of the reading.) Record the volume shown on the graduated cylinder as the initial base reading Item (17), SCS-530A, Figure 4-4 (back).

3. Reverse the bulb and insert the vacuum end in the coupler. Pump the balloon back into the cylinder and close the control valve. Remove the "Volumeasure" from the base plate.

4. With the density plate still in position on the material to be tested, dig through the hole in the plate to a depth sufficient to produce a hole having a volume which will meet the criteria specified in the Sand Cone Method. Retain all the material which is removed from the hole and place in an air-tight container. The weight of the material and the container is recorded as Item (20), SCS-530A, Figure 4-4.

5. Reset the "Volumeasure" in the recess in the base plate, open the control valve and pump the balloon into the hole (see Figure 4-9C). Read the lowest point reached by the water on the calibrated cylinder (this operation should be repeated to verify the accuracy of the reading) and record under Item (16), SCS-530A. The difference between the initial reading and this last reading is the volume of hole occupied by the soil sample in cubic feet Item (18), SCS-530A.

6. The balance of the in-place density test follows the same procedure as outlined for the Sand Cone Method. Test No. S-2, refer to Figure 4-4 and 4-4 (back).

A.- Equipment used in determining in-place density by Rubber Balloon Method.

B. - Obtaining initial calibration reading on Volumeasure (note surface of water column).

C. - Obtaining final reading. Balloon and water filling hole from which sample was taken. (Note surface of water column.)

Figure 4-9

Field Density Test - Calibrated Cylinder Method

General.

This method of determining in-place density of soils is applicable in soils that are free of gravel, stones, or other material which would make it difficult to drive or press the sampling cylinder into the soil. The method provides a reasonable degree of accuracy and is relatively simple to perform. Personnel experienced in the technique of this method are able to judge within rather close limits whether compaction requirements have been met, by the manner in which the cylinder penetrates the material being tested. Obviously, this preliminary observation should be taken as an indication, not as a conclusive test result.

Apparatus.

Equipment required for this test consists of the following:

1. Equipment for driving and removing the calibrated cylinder. Figure 4-10 shows the details of the required equipment. Equipment of this type can be procured from some of the test equipment manufacturers or it may be fabricated in a machine shop. The handle and drop weight assembly can be deleted when the cylinder is inserted by jacking force.

2. Two or three calibrated cylinders. These are cylinders of known volume manufactured from 2 inch to 6 inch diameter thin-walled pipe, with hardened beveled cutting edge.

3. Balance of 25 pound capacity, sensitive to 0.01 pound.

4. Hydraulic jack (appro. 1-1/2 T. capacity) suitable for forcing calibrated cylinder into compacted embankment. (Optional equipment.)

5. Spade or shovel for removing the calibrated cylinder and soil sample from the embankment.

6. Straightedge or large butcher knife for trimming sample.

7. Several jars or covered cans to hold soil samples for moisture determinations.

An array of equipment used in performing the field density test by the calibrated cylinder method is shown in Figure 4-11A.

Test Procedure.

The procedure outlined below is applicable to this test.

1. The volume of the cylinder is recorded as Item (19), SCS-530A or Item (10) SCS-530B and the cylinder is weighed empty to the nearest 0.01 pound and the weight recorded under Item (21), SCS-530A or Item (12) SCS-530B (see Figure 4-11B).

2. An area on the embankment is selected for taking the sample. The uncompacted surface material is removed and leveled as shown in Figure 4-11C.

3. A calibrated cylinder with a volume equal to that specified in the Sand Cone Method is driven into the compacted fill by means of the weight attached to the sampler rod (see Figure 4-11D), or by using a hydraulic jack placed on top of the cylinder and working against a pickup truck or other equipment to exert the necessary force.

4. When the top of the cylinder has been driven or forced below the ground surface, the driving assembly is detached. Use care not to overdrive the cylinder. The area around the outside of the cylinder is removed by means of a spade (see Figure 4-11A) and the column of soil is severed below the base of the cylinder to permit removal of the cylinder and the compacted sample (see Figure 4-12B).

5. Excess soil is then removed by trimming flush with the ends of the cylinder (see Figure 4-12C).

6. The cylinder and soil sample are weighed (see Figure 4-12D) and the weight recorded under Item (20), SCS-530A, or Item (11) SCS-530B.

7. A representative sample of the material passing the No. 4 sieve is immediately removed from the cylinder and placed in an airtight container for use in determining moisture content. The size of this sample should meet the criteria specified in the Sand Cone Method, Test No. S-2.

8. The remainder of the test follows the same procedure outlined for the Sand Cone Method, Test No. S-2.

This test is best suited for fine grained soil and items dealing with rock on Forms SCS-530A or SCS-530B may not always apply.

This method is suitable, however, for testing plastic shales.

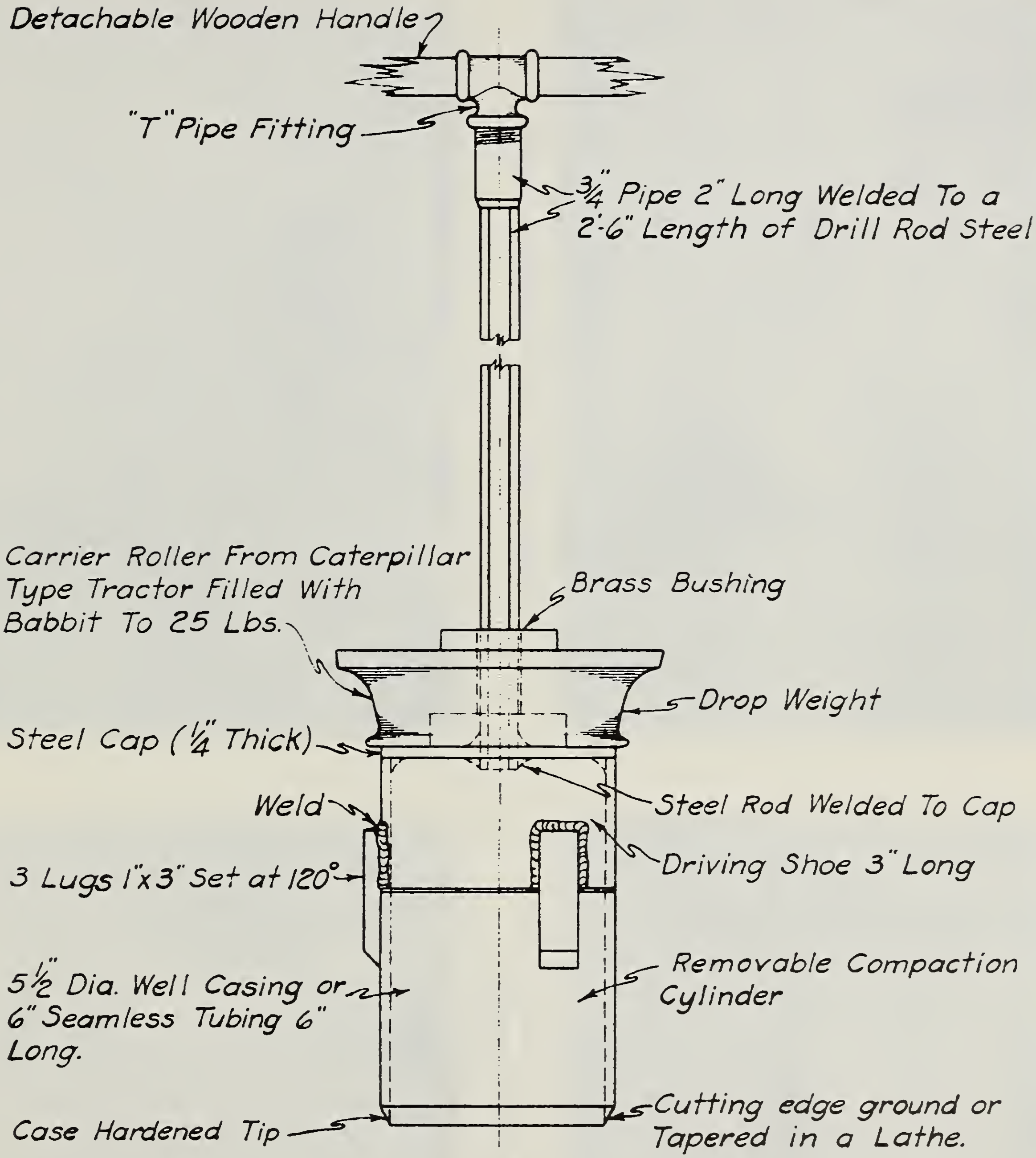
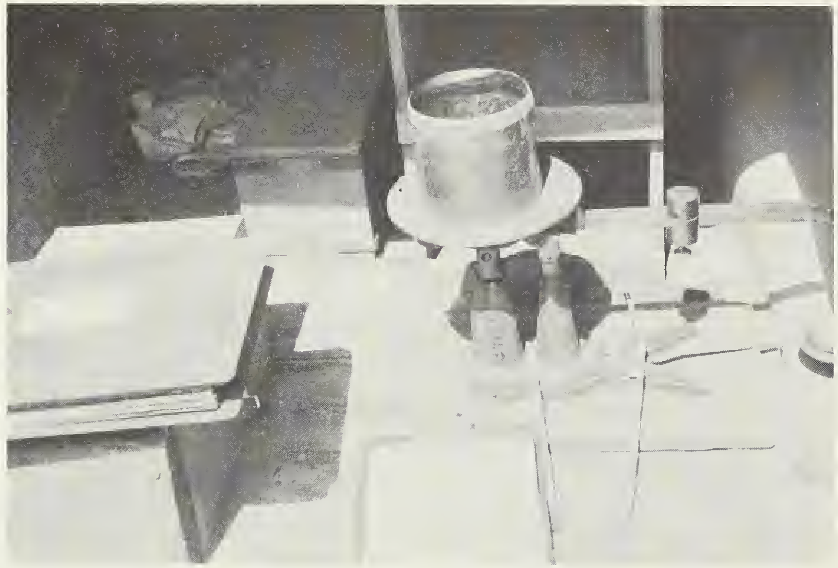


Figure 4-10 - Sketch of calibrated cylinder compaction sampler

A. - Equipment used in performing test by calibrated cylinder method.



B.- Weighing empty calibrated cylinder.

C. - Preparing surface of embankment preparatory to making test.

D.- Driving cylinder into embankment.

Figure 4-11

A. - Removing material around cylinder.

B. - Separating sample from underlying material.

C. - Trimming excess material at ends of cylinder.

D. - Weighing cylinder and compacted soil sample.

Figure 4-12

Test No. S-5

Field Density Test - Kerosene Method

General.
For the kerosene method of testing, the in place density is made on an undisturbed sample of the compacted earthfill. Due to the test procedures the method has certain limitations; (1) the fill material should consist primarily of fine grain soil which will form a solid dense mass when compacted, and (2) the fill material should be free from large fragments of stone or gravel.

Apparatus.

1. Balance of 500-1000 gram capacity, sensitive to 0.1 gram.

2. Pan or similar container, approximately 6" diameter by 6" depth.

3. Volumeter with overflow tube outletting at about 2/3 capacity of the unit.

4. Graduate of minimum 500 cc capacity.

5. Supply of kerosene with satisfactory container to give protection from contamination and fire hazard.

6. Tile spade, chisel, knife and sealed cans, for removing and transporting test samples.

7. Adequate equipment for drying sample for moisture determination.

Test Procedure.
The procedure for taking a sample for a density test requires special care in order to avoid cracking of the sample or increasing its density. The sample is ordinarily obtained by removing the loose surface material over an area, and then excavating around a 4-6 inch column of undisturbed compacted soil to a depth of about 6 inches. The undisturbed column is then carefully cut off near the base of the excavation and the material immediately placed in a tight container that will prevent loss of moisture.

The sample should be moved to the field laboratory as soon as possible after removal from the fill. Precautions should be taken to prevent damage to the sample in the interim.

Form SCS-530A may be used to record data for moisture and density determination (see Figure 4-4).

The following steps are taken in making the test at the laboratory:

1. The sample is divided into two portions, one of approximately 200 grams for the moisture test, and the other should be trimmed to such size as to displace slightly less than 500 cc.

2. The moisture determination is made on the small sample by one of the methods described for determining moisture content. Record data on SCS-530A, items (1) to (8).

3. The portion for the density determination should be carefully handled. All loose particles and protrusions should be trimmed off. The sample should be weighed without delay after preparation to avoid loss of moisture. Record in grams as item (24) SCS-530A.

4. After weighing, place sample in pan containing sufficient kerosene to provide complete coverage. This can best be done by placing the sample in a sling or net made of strong thread and gently lowering the sample into the liquid. Leave the sample submerged until air ceases to escape from the voids.

5. Fill the volumeter to overflow level with kerosene. When liquid ceases to drip from the overflow, place a clean 500 cc graduate under the spout. Make sure spout is positioned so that a minimum amount of dripping occurs at overflow level.

6. Remove sample from pan of kerosene and blot gently with dry cloth to remove excess fluid.

7. Using thread sling, carefully lower sample into the volumeter. After flow ceases from overflow spout, read the volume of kerosene contained in the graduate. Record in cubic centimeters, item (27).

   This reading is equivalent to the volume of the soil sample.

8. The density is computed by substituting the weight and the volume of the specimen in the following formula:

   $$\text{Wet density} = \frac{\text{Weight of test sample in grams}}{\text{Volume of sample in cc}}$$

   and

   $$\text{Dry density} = \frac{\text{Wet density} \times 100}{100 + \%\ \text{moisture}}$$

   The dry density may be recorded as item (29) SCS-530A.

Test No. S-6

Method for Rapid Determination of Density and Moisture

General.
This test procedure is especially applicable for use at construction sites that have borrow materials which consist of variable soil or zones of differing grain sizes. Even though extra precaution is taken to operate the borrow areas to produce uniformity, fill materials from these areas can produce appreciable variation in moisture requirements and density results.

It should be recognized that for these conditions the use of laboratory or infrequently prepared standard moisture density curves to determine acceptable in place density, may result in serious error.

Test No. S-6 provides a method of density control usable for soils containing less than 35 percent, + No. 4 size, which is based on maximum compacted density obtained for the same material for which the in place density was determined in the embankment. The results obtained are adequate for contract control and can be determined with a minimum amount of equipment and time.

In a study concerned with the properties of compacted cohesive soils by the U. S. Bureau of Reclamation, it became apparent that exact information on the ratio of dry density of fill to laboratory dry density at fill moisture was readily available without knowing the water content. In addition, it was found that by compacting various specimens in the compaction test procedure and recording the amount of water added to or taken from the soil as a percentage of fill wet weight, a wet density curve could be obtained. This curve could then be converted to wet density on a fill water content basis, from which the exact percentage of fill dry density to specified maximum dry density can be obtained. This percentage criterion for density control is used by SCS, and since it can be determined without drying the soil samples, the major time-consuming operation can be avoided.

The method and nomenclature used in this test writeup is based on USDI, Bureau of Reclamation, Engineering Monograph No. 26, as revised in September 1961. This monograph was written by Jack W. Hilf.

The following nomenclature and definitions are used in the test procedure and computations:

w_f = fill water content expressed as a percent of contained water with respect to oven dry weight.

w = percent moisture

w_o = optimum moisture content (percent).

z = amount of water added to or dried from the sample in percent of fill wet weight.

z_m = abscissa of peak point of $od(1+w_f)$ versus z curve.

z_1, z_2 = abscissa of points used in plotting $od(1+w_f)$ versus z curve.

γd_c = cylinder dry density.

γd_f = fill dry density.

γw_c = cylinder wet density.

γw_f = fill wet density.

γd_m = specified maximum dry density.

γd_1, γd_2, od_3 = dry densities at points 1, 2, 3, or $\gamma d(1 + w_f)$ versus z curve.

C = ratio of fill wet density to cylinder wet density.

D = ratio of fill dry density to specified maximum dry density.

y_m = ordinate at peak point of $\gamma d(1 + w_f)$ versus z curve.

Consider a field density test made in soil containing no gravel. (The procedure in soils containing gravel is similar, except for the screening required and the computations necessary to obtain the fill wet density of the minus No. 4 fraction.) The material obtained from the test hole is protected against evaporation and is compacted by a standard method and equipment, while at fill water content, w_f, to what is called a "cylinder" wet density, γw_c.

The ratio of fill wet density, γw_f, to "cylinder" wet density is identical with the ratio of their dry densities, since both wet densities are at the same water content:

$$\frac{\gamma w_f}{\gamma w_c} = \frac{\gamma d_f(1 + w_f)}{\gamma d_c(1 + w_f)} = \frac{\gamma d_f}{\gamma d_c} = C \qquad \text{Equation (1)}$$

The value of the ratio, C, indicates the relation between the compactive effort used on the fill and the specified compactive effort.

The ratio D, of fill dry density to specified maximum dry density, which is the basis of density control, can be obtained from wet densities in a similar manner if the value $\gamma d_m(1 + w_f)$ is found. The value D can be obtained by dividing the fill wet density by this quantity:

$$D = \frac{\gamma d_f(1 + w_f)}{\gamma d_m(1 + w_f)} = \frac{\gamma d_f}{\gamma d_m} \qquad \text{Equation (2)}$$

The rapid method is a procedure for obtaining the value $\gamma d_m(1 + w_f)$.

A sample of soil was taken from a fill with a water content, w_f, somewhat less than optimum, and compacted in a cylinder in a specified manner. If the resulting "cylinder" dry density is od_c, then the "cylinder" wet density will be: $\gamma d_c(1 + w_f)$.

For any fill water content, w_f, the value of the "cylinder" wet density can be readily obtained by a compaction test. Let this point be the origin of new curves obtained by translating the origin of the abscissas, to the fill water content. Also, use for the abscissa of the new curves, the amount of water added to the soil in percentage of fill wet weight (z). This change in origin is equivalent to considering the moist soil removed from the fill to be "dry"; that is, the water associated with the soil at fill water content is treated as solid material. Values of z are in percentage of "dry" weight by this concept.

By adding water to samples of the moist soil (all samples are at fill water content to start with), and by mixing and compacting them in the usual manner, a wet density versus z curve is obtained. The values of ordinates of this curve are the same as the wet density curve. However, the abscissas are values of z rather than of w. The analogy between the standard compaction wet density curve and the new curve can be completed by drawing the converted wet density curve. This is done by dividing each ordinate of the upper curve by (1 + z). The resulting curve is similar in shape to the dry density curve. The values of the ordinates of the converted wet density curve are not dry density, however, but are dry density multiplied by the expression $(1 + w_f)$.

It should be noted that the basic or standard compaction curves cannot be drawn unless the values of water content are determined, whereas the new curves presented in this procedure are compaction curves and can be drawn without knowing values of water content.

The values of z, used in the curves presented herein, are merely the ratios of pounds of water added to pounds of moist soil removed from the fill, and are known. Hence, the value of the ratio of fill dry density to laboratory maximum dry density, D, can be obtained precisely from wet densities alone by finding the peak point of the $\gamma d(1 + w_f)$ curve. This curve is obtained by plotting the points:

(1) $\gamma d_1(1 + w_f)$

(2) $\dfrac{\gamma d_2(1 + w_2)}{1 + z_2}$

(3) $\dfrac{\gamma d_3(1 + w_3)}{1 + z_3}$

etc. It should be noted that $z = \dfrac{w - w_f}{1 + w_f}$ can be negative as well as positive.

The determination of the maximum ordinate of the $\gamma d(1 + w_f)$ versus z curve presents the same problem one encounters in finding the maximum dry density in a dry density versus water content curve. Generally, the more points that are plotted, the more accurate is the determination of the peak point of the converted wet density curve. The minimum number of points needed is three, and if these are spaced so that the point of maximum ordinate falls within the range of their abscissas, the maximum ordinate can be determined graphically. This is done by assuming the portion of the $\gamma d(1 + w_f)$ versus z curve in the vicinity of the maximum point to be a parabola whose axis is parallel to the $\gamma d(1 + w_f)$ coordinate axis. The parabola method of locating the maximum ordinate is given below. Its use is not essential to the rapid method, but it has been found advantageous in reducing the number of points required and it provides a unique value for the peak point without sketching the curve.

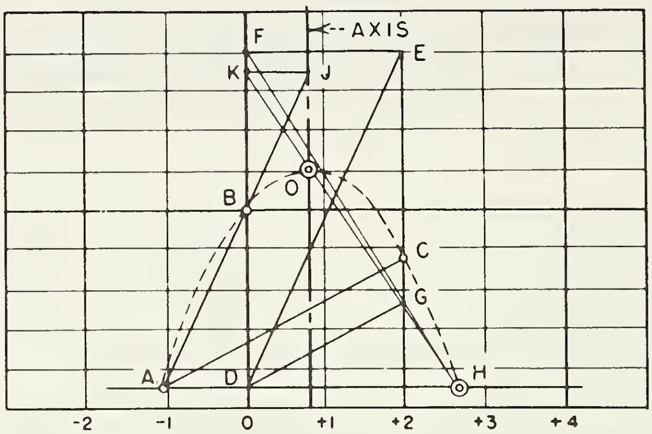
Parabola Method.
Given three points on a parabola similar to the $\gamma d(1 + w_f)$ versus z curve, whose axis is parallel to the $\gamma d(1 + w_f)$ axis.

Figure 4-13 describes the graphical solution for z_m and y_m the vertex of the parabola.

In a further effort to simplify the procedure to obtain D, the coordinate sheet on which the curve is plotted is provided with a series of diagonal lines which enables the division of wet density by the quantity (1 + z) to be done graphically, so that points of

Parabola Method

Graphical solution for vertex, O, of a parabola whose axis is vertical, given three points A, B, and C. If more than three points are available, use the three closest to optimum.



1. Draw horizontal base line through the left point, A, and draw vertical lines through points B and C.
2. Draw line DE parallel to AB, point E lies on the vertical line through point C; project E horizontally to establish point F on the vertical line through B.
3. Draw line DG parallel to AC, point G lies on the vertical line through point C.
4. Line FG intersects the base line at H. Axis of parabola bisects AH; draw the axis.
5. Intersection of line AB with the axis is at J; project J horizontally to K, which lies on the vertical line through point B.
6. Line KH intersects the axis at O, the vertex.

NOTE: If points A, B, and C are equally spaced horizontally (this is true when 2 points are obtained by adding water or when soil is dried exactly 2 percent) steps 2 and 3 above are eliminated. Point F coincides with point B and point G is halfway between the base line and point C. Hence, point H is obtained by drawing BG and point O is obtained by steps 5 and 6 as usual. See graph below.

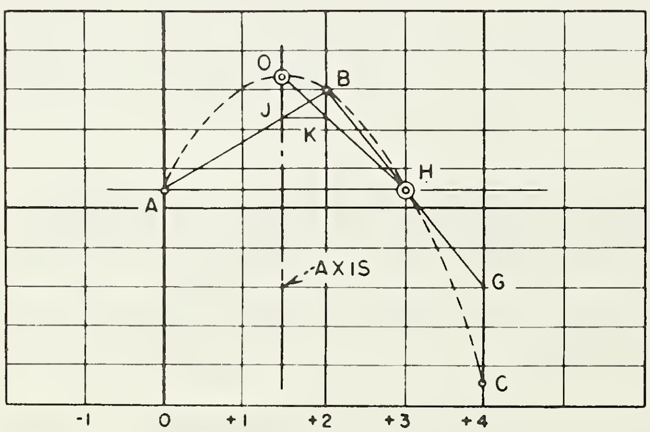


Figure 4-13 - Graphical solution for peak point of parabola

coordinates $[(z), \gamma d(1 + w_f)]$ can be plotted without using a slide rule or calculating machine. Once the maximum ordinate, $\gamma d_m(1 + w_f)$ is obtained, the value of the ratio of fill dry density to specified maximum dry density, D, can be obtained graphically by using the diagonal lines as explained later in the examples.

Moisture Control.

The location of the peak point of the $\gamma d(1 + w_f)$ versus z curve shows whether the soil is at optimum water content (w_o), or is less than or greater than optimum. However, the exact magnitude of the difference between optimum water content and fill water content is unknown. From Equation (3), it follows that:

$$w_o - w_f = z_m (1 + w_f) \qquad \text{Equation (3)}$$

For $z_m = 0$, $w_o - w_f = 0$ for any value of w_f. For values of z_m other than 0, the magnitude of w_f is needed to obtain $w_o - w_f$.

It can be shown that:

$$1 + w_f = \frac{1 + w_o}{1 + z_m} \qquad \text{Equation (4)}$$

Another expression for the difference between optimum and fill water contents is obtained by combining Equations (3) and (4):

$$w_o - w_f = \frac{z_m}{1 + z_m} (1 + w_o) \qquad \text{Equation (5)}$$

Since neither w_f nor w_o is known, Equations (3) and (5) require that one of these values be estimated in order to obtain the magnitude of $w_o - w_f$. However, an error in estimating w_f or w_o results in a much smaller error in the value of $w_o - w_f$. For example, in Equation (5), for $z_m = +0.02$, an error of 0.05 in estimating w_o is reduced to $\frac{0.02}{1.02} (0.05) = 0.00098$ for $w_o - w_f$; this small error is acceptable for control purposes.

To avoid the necessity of estimating w_f or w_o for each density test, a set of curves were prepared which automatically estimates w_o for the coordinates of the peak point of the converted wet density curve.

These lines show the correction value to be added to z_m to give $w_o - w_f$. The correction value shown by the curved lines (to the nearest 0.1) closest to the peak point of the converted wet density curve $[\text{coordinates } z_m, \gamma d_m(1 + w_f)]$ is added algebraically to z_m to give a value for $w_o - w_f$ that is sufficiently accurate for control purposes.

Examples.

Procedure for determining density and moisture:

Obtain fill density of minus No. 4 fraction by test No. 5-2, 5-3, 5-4 or 5-5.

Then to determine (d), the ratio of fill dry density to specified maximum dry density, and $w_o - w_f$ in percent, proceed as follows:

To obtain Point (1).--Compact soil at fill water content into a standard cylinder. Plot the resulting wet density on the 0 percent vertical line on Figure 4-14.

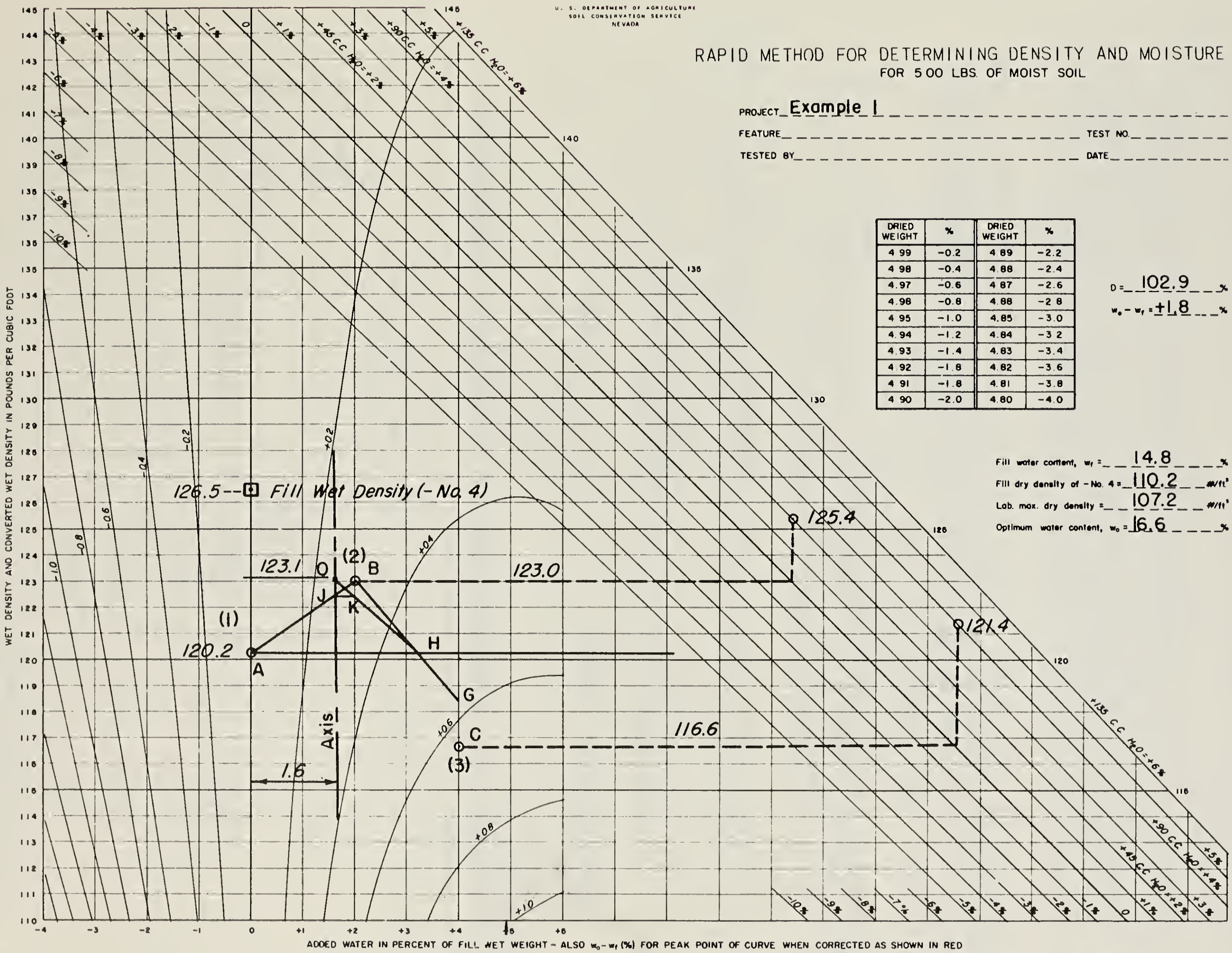
Note: Form SCS-541 was developed by the Service from the material presented by Mr. Hilf, except a change in procedure which reduces the size of the soil sample from 7.5 pounds to 5.0 pounds. The necessary changes in the procedural write up were also made accordingly.

To obtain Point (2).--To 5.00 pounds of soil at fill water content add 45 cubic centimeters (2 percent) water, mix, and compact into a cylinder to determine wet density. Find the point on the +2 percent diagonal line corresponding to the wet density; project vertically to the 0 percent diagonal line, thence horizontally to plot Point (2) on the +2 percent vertical line. The ordinate of the plotted point is the wet density divided by 1.02.

To obtain Point (3).--If Point (2) is greater in ordinate than Point (1): To 5.00 pounds of soil at fill water content add 90 cubic centimeters (4 percent) water, mix and compact into a cylinder. Find the point on the +4 percent diagonal line corresponding to the wet density; project vertically to the 0 percent diagonal line, thence horizontally to plot Point (3) on the +4 percent vertical line. The ordinate of the plotted point is the wet density divided by 1.04.

If Point (2) is smaller in ordinate than Point (1): Permit 5.00 pounds of soil at fill water content to dry without loss of soil; then weigh. The table on the right-hand portion of SCS-451, Figure 4-14, gives the percentage of water loss corresponding to the dried weight. Compact the dried soil into a cylinder. Find the point on the diagonal line (interpolate if necessary) corresponding to the wet density; project vertically to the 0 percent diagonal line, thence horizontally to plot Point (3) on the vertical line corresponding to the correct percentage. The ordinate of the plotted point is the wet density divided by 1 plus the negative percentage: $\left[1 + (-0.02) = 0.98\right]$

Three plotted points are sufficient if both the left and right points are lower in ordinate than the center point; if not, a fourth point is necessary. Find the point of maximum ordinate of the curve by



DRIED WEIGHT	%	DRIED WEIGHT	%
4.99	-0.2	4.89	-2.2
4.98	-0.4	4.88	-2.4
4.97	-0.6	4.87	-2.6
4.96	-0.8	4.86	-2.8
4.95	-1.0	4.85	-3.0
4.94	-1.2	4.84	-3.2
4.93	-1.4	4.83	-3.4
4.92	-1.6	4.82	-3.6
4.91	-1.8	4.81	-3.8
4.90	-2.0	4.80	-4.0

Figure 4-14 - Example in which fill water content is less than optimum

the parabola method, or by sketching the curve if the number and locations of the points permit accuracy without use of the parabola method.

Plot the fill wet density of minus No. 4 fraction on the 0 percent vertical line.

To obtain D.--Project the maximum ordinate horizontally to the 0 percent diagonal line, thence vertically to the value of the fill wet density. D = 100 percent plus the interpolated percentage given by the diagonal lines, taking minus signs into account. D is fill wet density divided by the maximum ordinate of the curve.

To obtain $w_o - w_f$.--This value is the abscissa of the point of maximum ordinate corrected by adding the value shown in red (the curved lines) on the chart nearest to the peak point, interpolating where necessary, and taking minus signs into account.

Completion of Test for Record Purposes.
Dry a sample of minus No. 4 fraction to constant weight in an oven at 110° C to obtain fill water content, w_f. Then:

$$\text{Fill dry density of -No. 4} = \frac{\text{Fill wet density of-No. 4}}{(1 + w_f)}$$

$$\text{Laboratory maximum dry density} = \frac{\text{Maximum ordinate}}{(1 + w_f)}$$

$$\text{Optimum water content} = w_f + (1 + w_f)z_m$$

Example 1.
Figure 4-14 is an example in which the fill water content is less than optimum. The test data are:

Fill wet density = 126.5 pounds per cubic foot.

Point	Wet density in pounds per cubic foot	z In percent	Converted wet density in pounds per cubic foot
(1)	120.2	0	120.2
(2)	125.4	2	123.0
(3)	121.4	4	116.6
By the parabola method			
0	--	1.6	123.1

then,

$$D = \frac{126.5}{123.1} = 102.9 \text{ percent}$$

$$w_o - w_f = +1.6 + 0.2 = +1.8 \text{ percent (dry of optimum)}$$

These values are sufficient to accept or reject the compacted fill according to criteria established for the work.

After the fill water content has been determined by drying a sample to constant weight at 110° C, the field density test is completed for record purposes as follows:

$$w_f = 14.8 \text{ percent}$$

$$\gamma d_f = \frac{126.5}{1.148} = 110.2 \text{ pounds per cubic foot}$$

$$\gamma d_m = \frac{123.1}{1.148} = 107.2 \text{ pounds per cubic foot}$$

$$w_o = 0.148 + 1.148\ (.016) = .166 \text{ or } 16.6 \text{ percent}$$

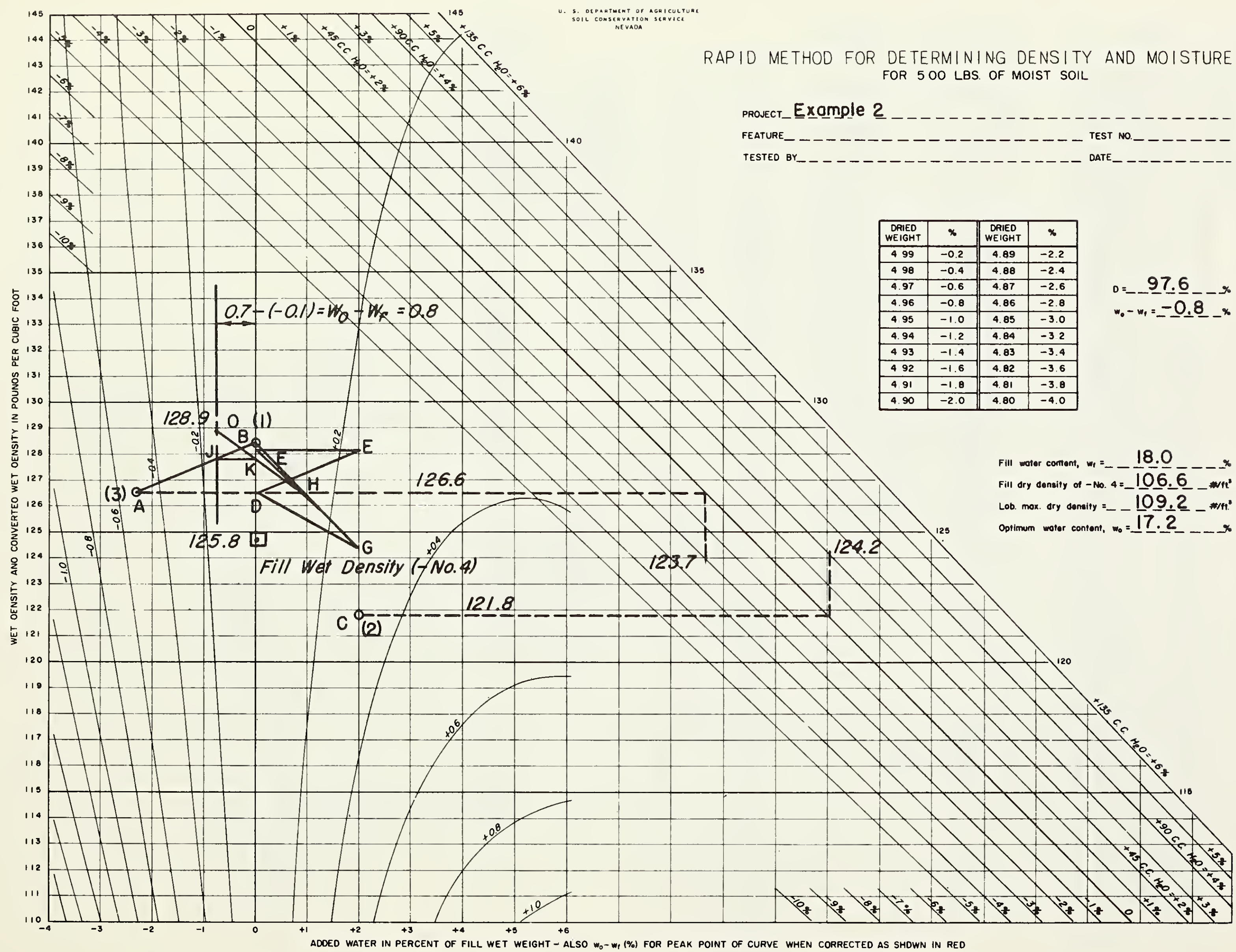
Example 2.
Figure 4-15 is an example in which the fill water content is greater than optimum. The test data are:

Fill wet density = 125.8 pounds per cubic foot.

Point	Wet density in pounds per cubic foot	z in percent	Converted wet density in pounds per cubic foot
(1)	128.4	0	128.4
(2)	124.2	+2	121.8
(3)	123.7	-2.3	126.6

By the parabola method

0	--	-0.7	128.9



DRIED WEIGHT	%	DRIED WEIGHT	%
4.99	-0.2	4.89	-2.2
4.98	-0.4	4.88	-2.4
4.97	-0.6	4.87	-2.6
4.96	-0.8	4.86	-2.8
4.95	-1.0	4.85	-3.0
4.94	-1.2	4.84	-3.2
4.93	-1.4	4.83	-3.4
4.92	-1.6	4.82	-3.6
4.91	-1.8	4.81	-3.8
4.90	-2.0	4.80	-4.0

Figure 4-15 - Example in which fill water content is greater than optimum

then,

$$D = \frac{125.8}{128.9} = 97.6 \text{ percent}$$

$$w_o - w_f = -0.7 \ -0.1 = -0.8 \text{ percent (wet).}$$

These values are sufficient to accept or reject the compacted fill according to criteria established for the work.

After the fill water content has been determined by drying a sample to constant weight at 110° C, the field density test is completed for record purposes as follows:

$$w_f = 18.0 \text{ percent}$$

$$\gamma d_f = \frac{125.8}{1.18} = 106.6 \text{ pounds per cubic foot}$$

$$\gamma d_m = \frac{128.9}{1.18} = 109.2 \text{ pounds per cubic foot}$$

$$w_o = 0.18 + (1.18)\ (-0.007) = 0.172 \text{ or } 17.2 \text{ percent.}$$

Test No. S-7

Moisture-Density Relations of Soil

General.
This test is used for determining the relationship between molding moisture content and dry density under the action of any given compactive effort. The method was originated by R. R. Proctor for the purpose of duplicating in the laboratory a degree of compaction comparative to that secured with certain types of construction equipment.

The procedure outlined for this field test is the same as used in the laboratory and conforms to the requirements set forth in the standard tests method by ASTM Designation D-698, "Test for Moisture-Density Relations of Soils Using 5.5 lbs. Rammer and 12 inch Drop.", or A.A.S.H.O., Designation T-99, "Standard Method of Test for the Compaction and Density of Soils."

Laboratory soil tests are usually available for the job, based on test samples taken from the borrow sources. If it is determined that the available laboratory test results are not representative of the materials being placed, it then becomes necessary to make field compaction tests and prepare new curves or use the Rapid Test Procedure, Test No. S-6. It is extremely important that test samples are representative of the materials and moisture conditions that exist at the site. Samples taken from the borrow area or the embankment should be transported in closed containers if the field moisture content is of importance. A total sample consisting of about 30 pounds of minus #4 material should be obtained. The amount of sample should be adequate for the performance of the required compaction tests without resorting to reuse of the sample materials.

The equipment required and the procedure for running the compaction test is as outlined below:

Note: This test may also be performed on minus 3/4 inch material when gravelly soils are involved.

Apparatus.
(1) Cylinder mold - 4" diameter by 4.59 inches high capacity, 1/30 cu. ft. split type preferred, detachable base plate and 2.5 inch high removable extension collar.

(2) Metal rammer with 2 inch diameter striking face, weight of hammer 5.5 pounds, equipped with suitable guide for controlling the direction and height of drop to a free fall of 12 inches.

(3) Weighing scale of 25 pound capacity, sensitive to 0.01 pound.

(4) Balance of at least 1000 gram capacity, sensitive to 0.1 gram.

(5) Number 4 standard sieve (approx. 1/4 inch).

(6) Large mixing pan.

(7) Straight edge having one beveled edge or large knife to shave soil samples.

(8) Drying oven with thermometer. If electric oven is used it should be of sufficient size to permit drying several samples at one time, be equipped with thermostatic control having a response sensitivity of $\pm$ 1/2°C., temperature range of approximately 40° C. to 200°C., supplied with 110/120 volt 50/60 cycle AC operation, 1600 watts (maximum). Thermometer should be general laboratory type with range from 0-260°C.

(9) At least 6 small cans with covers (aluminum preferred) for holding specimens for moisture determinations.

(10) Miscellaneous tools such as trowel, scoop or large spoon for handling loose soil, rolling pin or equivalent to break up soil lumps, and a wash bottle with perforated top to sprinkle water on the soil sample.

Note: When minus 3/4 inch material is used for the test, a mold 6" in diameter by 4.59 inches in height is generally used in lieu of the standard size mold.

Preparation of Soil Sample.

If the soil sample contains aggregate which exceeds 1/4 inch size, the soil should be air dried so that the lumps and clods can be broken and the sample screened over a No. 4 screen. Care should be exercised in handling materials containing soft or friable rock to prevent undue breakdown of the particles that would result in changes of gradation. Aggregates representing less than 5 percent by weight of the total sample may be disregarded. The material passing the No. 4 screen should be broken down and thoroughly mixed. Each mold will require about 5 to 6 pounds of screened sample.

Test Procedure.

1. The compacting equipment should rest on a firm support throughout the test. (A.S.T.M. procedure specifies a concrete block of at least 200 lbs. weight.)

2. Weigh the mold with base plate and without the collar on the 25 pound scales (see Figure 4-16A) and record weight under Item 2, Figure 4-18.

3. Lightly grease the mold and attach collar.

4. Thoroughly mix the slightly damp soil material and compact in the mold (extension collar in place) in three equal layers, each layer receiving 25 blows from the rammer dropped from a height of one foot above the soil. See that for each layer the 25 blows are uniformly distributed over the surface of the specimens (see Figure 4-16B and 4-16C). Check the contract to determine the total compactive effort specified - No. of blows may be modified. The standard test procedure specifies that 56 blows be applied to each of the three layers when the 6 inch diameter mold is used.

5. Remove the extension collar and carefully trim the sample flush with the top of the mold (see Figure 4-16D). Weigh the cylinder, base plate and sample (see Figure 4-17A) and record weight under Item 1 - Figure 4-18.

6. If the Standard Resistance to Penetration Test is to be made, the top of the molded sample should be tested (punched) three times, with the proctor needle immediately after weighing, and the results averaged. The average values are entered under Item 6, Figure 4-18. Detailed procedure for the Penetration-Resistance Test is also included in this chapter of the Handbook, (see Test No. 5-9). It is important that the specimen is not allowed to lose moisture between the time it is leveled off, weighed and tested with the proctor needle.

7. Take a moisture sample by cutting through the center portion of the three layers of compacted soil (see Figure 4-17B). Place a portion of the sample weighing not less than 100 grams in a moisture can, cover to prevent loss of moisture, and weigh (see Figure 4-17C). Record weight under Item 11, Figure 4-18.

Note: It is desirable to dry more than one sample for moisture content determination.

8. Dry samples in controlled oven (see Figure 4-17D) following the procedures outlined in "Standard Method of Determining Percent of Moisture." (Test No. S-10).

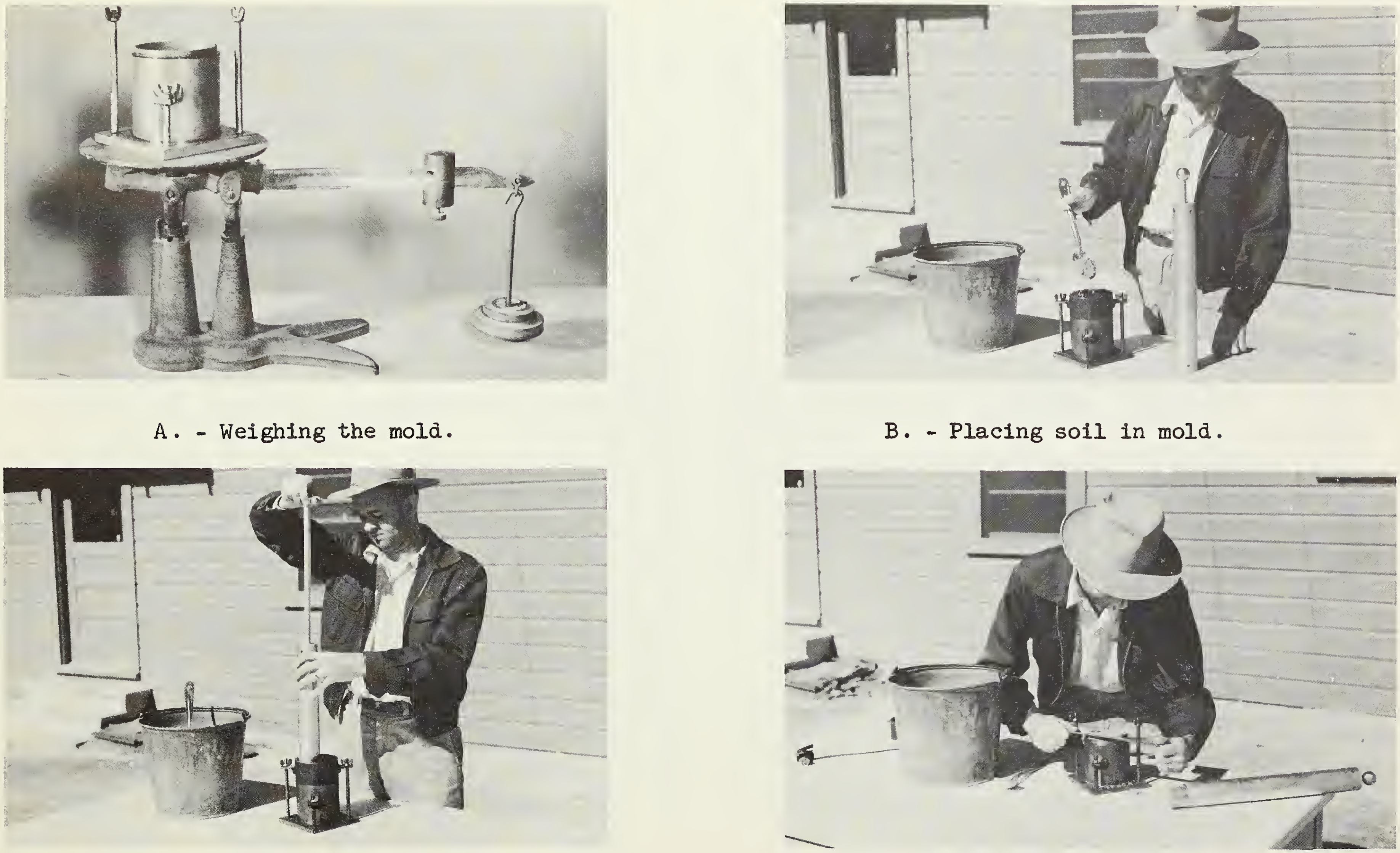
9. Process additional soil to pass the 1/4 inch screen and thoroughly mix with sufficient water to increase the moisture content approximately two percent. Cover the container to avoid evaporation and allow the sample to set for a few minutes to allow the moisture to penetrate throughout the test sample.

10. Repeat steps 3 through 9, each time adding approximately two percent more water until the soil becomes very moist and there is a substantial decrease in the wet weight of the compacted soil. A minimum of 4 to 5 compacted specimens at varying moisture content are necessary to provide well defined penetration resistance and moisture density curves.

Recording Data.

All data for calculations may be recorded on Form SCS-359 (Figure 4-18) entitled "Work Sheet for Compaction and Penetration Resistance Data."

The results of the compaction tests corrected for weight of moisture and expressed as pounds of dry soil per cubic foot (Item 5) are plotted against their respective moisture contents (Item 9) on Form SCS-352 entitled, "Compaction and Penetration Resistance Report," and a smooth curve drawn through the resulting points. Figure 4-19 shows a plotting of the data described herein. The peak of the curve represents the maximum density for the given material under the above method of compaction and is sometimes referred to as "Proctor maximum density." The percent of water at this point represents the moisture necessary to give maximum density for the specified compaction and is usually referred to as "optimum moisture." The peak of the curve will not necessarily be at the location established by one of the test specimens.



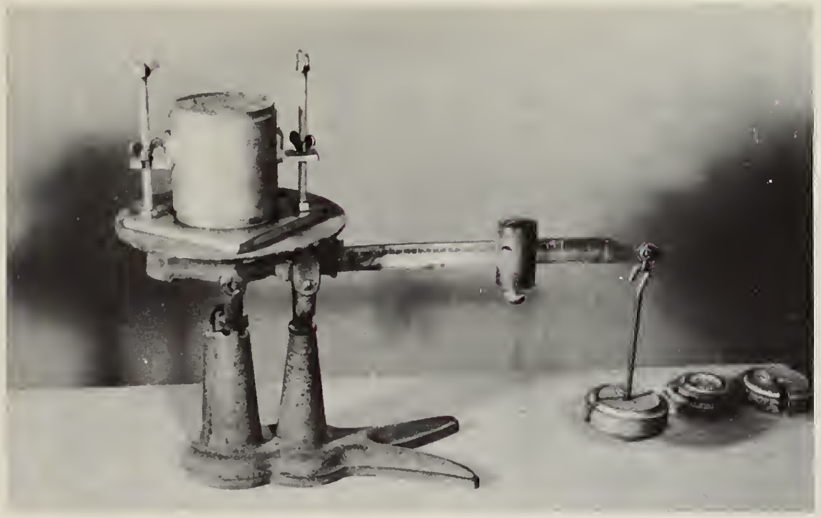
A. - Weighing the mold.

B. - Placing soil in mold.

C. - Compacting soil in mold.

D. - Trimming sample flush with the mold

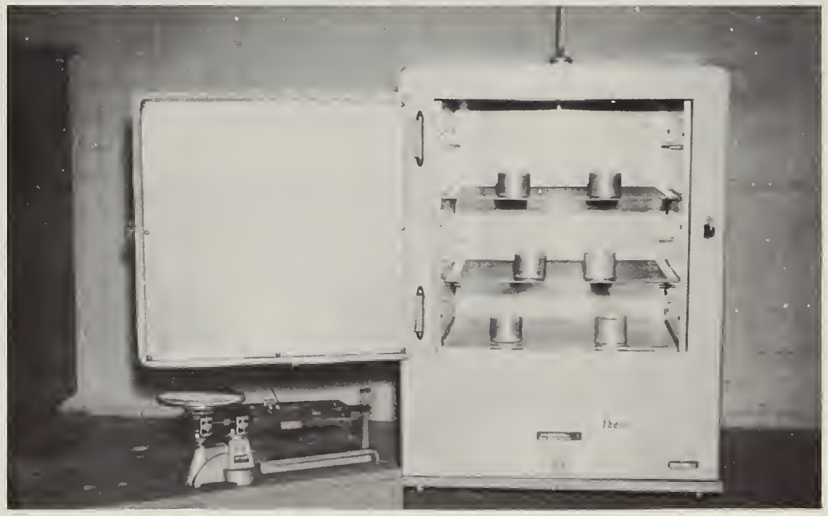
Figure 4-16



A. - Weighing mold and compacted sample.

B. - Obtaining soil sample for moisture determination.

C. - Weighing soil sample in moisture can.



D. - Samples in electric oven for drying.

Figure 4-17

SCS-359
(11/58)

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
SOIL MECHANICS LABORATORY

WORK SHEET FOR COMPACTION AND PENETRATION RESISTANCE DATA

Laboratory Sample No.: 17-58

COMPACTION DATA

(Record Weights in Pounds)

1	Wt. of Cyl. + Soil	8.87	9.22	9.45	9.57	9.61	9.58
2	Wt. of Cylinder	5.18	5.18	5.18	5.18	5.18	5.18
3	Wt. of Soil = 1 - 2	3.69	4.04	4.27	4.39	4.43	4.40
4	Wt. per Cu. Ft. (Wet) = 3 ÷ Vol. of Cyl.	110.7	121.2	128.1	131.7	132.9	132.0
5	Wt. per Cu. Ft. (Dry) = $\frac{4 \times 100}{100 + 9}$	105.0	111.6	116.1	117.0	116.4	113.4
6	Proctor Needle Readings	100+	91	80	61	39	8
7	Size Needle (Sq.in.)	1/20	1/20	1/20	1/20	1/20	1/20
8	Penetration (Lbs./sq. in.) Resistance = 6 ÷ 7	2000+	1820	1600	1220	780	160

MOISTURE DETERMINATION DATA

(Record Weights in Grams)

9	Percent Moisture = $\frac{13}{15} \times 100$	5.5	8.5	10.3	12.5	14.1	16.3
10	Can Number	1	3	4	5	6	7
11	Wet Wt. - Can + Soil	117.7	136.1	146.7	154.7	149.8	167.8
12	Dry Wt. - Can + Soil	113.0	127.5	135.5	140.5	134.5	148.0
13	Moisture Weight = 11 - 12	4.7	8.6	11.2	14.2	15.3	19.8
14	Weight of Can	27.0	26.0	26.5	27.0	26.0	26.5
15	Dry Weight of Soil = 12 - 14	86.0	101.5	109.0	113.5	108.5	121.5

Vol. of Cyl. 1/30 cu. ft.	
x	Standard Proctor
	Modified AASHO
	Other

PROCEDURE DATA:

Wt. of Hammer 5.5 Pounds

Drop 12 Inches

No. of Lifts 3 (25 blows each)

Completed by: CRS Date: 2-15-58

Computed by: CRS Date: 2-15-58

Checked by: WLL Date: 2-15-58

Recorded by: WLL Date: 2-15-58

Density		%
Wet	Dry	H_2O
132.8	117.2	12.0

Project Mill Creek

Site #2

Figure 4-18

SCS -352 (10/57)

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
SOIL MECHANICS LABORATORY

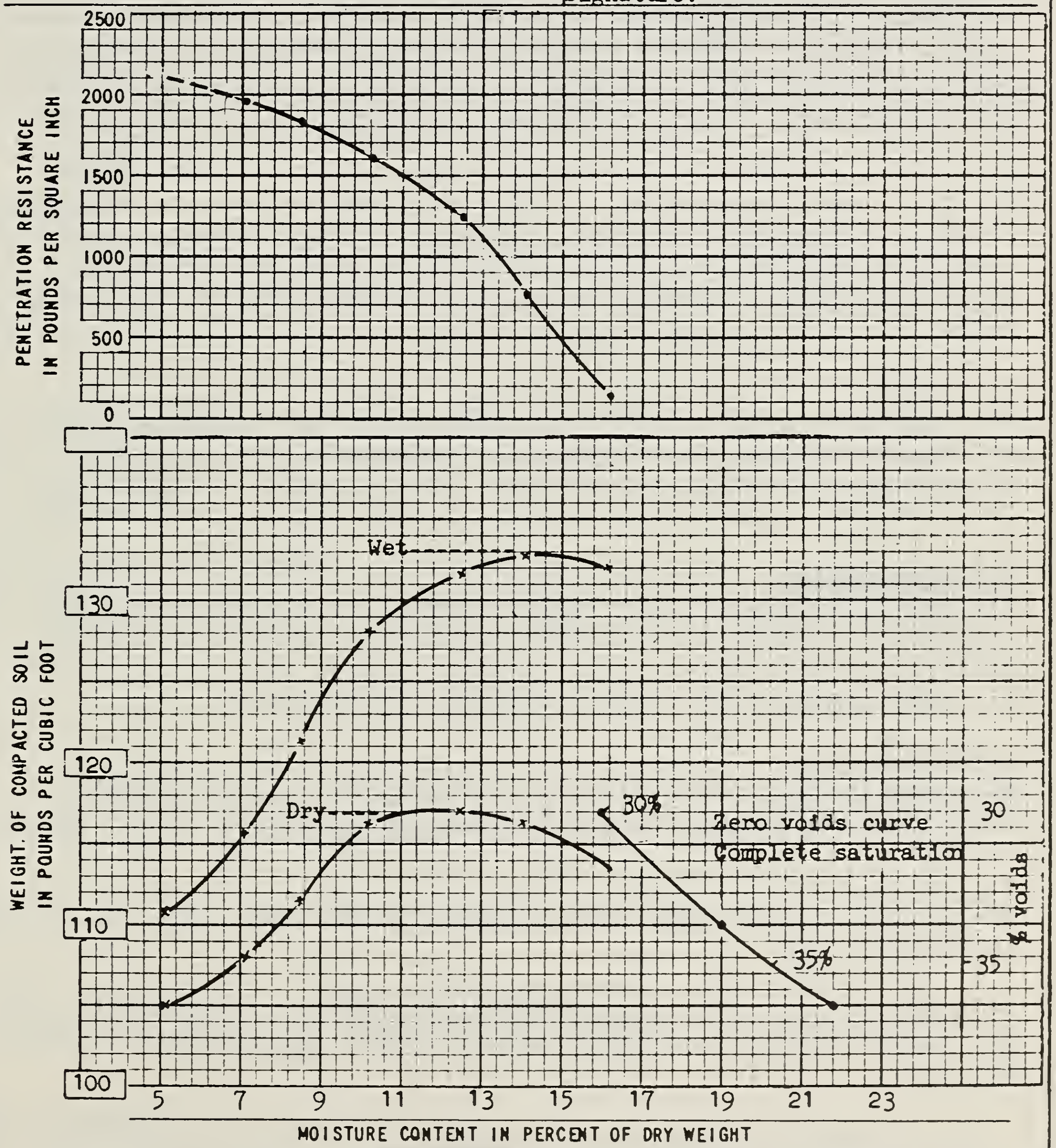
COMPACTION AND PENETRATION RESISTANCE REPORT

Date 2-15-58 Sample No.: Field 1 Lab 17-58

Project Mill Creek Location Site #2

Sample Location and Depth Boring A2-158 Borrow #1 1-5 ft.

Signature:



TYPE OF TEST	TEST PROCEDURE	Classification SM
[X] Standard Proctor	Weight of Hammer 5.5 Lbs.	100 % Material Compacted
[ ] Modified AASHO	Drop 12 Inches	Passed #4 Sieve
[ ] Other	Lifts 3 layers (25 blows each)	(Sp. Gr.) Gs - 2.65 gr/cc
	Vol. of Cylinder 1/30 Cu. Ft.	Curve of

Figure 4-19

Test No. S-8

Modified Test Moisture-Density Relation of Soil

General.

A modified moisture-density test has been developed to provide a basis for determining the density obtained through greater compactive effort, which more or less duplicates the use of heavy equipment now available and in general use by earth-moving contractors. Since the standard moisture-density test was designed to duplicate the effects of lighter compaction equipment, a definite need existed for the development of a modified test. This test is commonly referred to as the Modified AASHO Moisture-Density Test and is covered by the American Association of State Highway Officials test Designation; T-180, "The Moisture-Density Relations of Soils, Using 10 lb. Rammer and 18 inch Drop," Method A, and also ASTM Designation; D 1557, "Methods of Test for Moisture-Density Relation of Soils, Using 10 lb. Rammer and 18 inch Drop," Method A.

Apparatus.

The equipment used in this test differs from the Standard Method in that the weight of the rammer is increased from 5.5 pounds to 10 pounds and the drop is increased from 12 inches to 18 inches. In all other respects the equipment is the same for both methods.

Test Procedure.

The only difference in the modified method is the placement and compaction of the soil in 5 equal layers in the mold instead of 3 layers as specified for the Standard Method, Test No. S-7. In all other respects the test procedures are the same.

Recording Data.

Test results and calculations may be recorded on Form SCS-359, "Work Sheet for Compaction and Penetration Resistance Data," (Figure 4-18).

The individual test items are recorded in the same manner as outlined in Test No. S-7.

Test results may also be plotted on Form SCS-352, Figure 4-19, and the compaction and resistance curves plotted as mentioned in Test No. S-7.

Test No. S-9

Penetration Resistance of Soil

General.
The Proctor Needle is a device used to measure and record the moisture-penetration-resistance relations or plasticity of fine-grained soils. It is used principally as an approximate and rapid check on the moisture content of soil in borrow areas or an embankment. It may also provide an indication of the bearing capacity of a given soil to support earth moving and compaction equipment operating on an embankment. This test is covered by ASTM Designation D 1558, "Method of Test for Moisture-Penetration-Resistance Relations of Fine Grained Soils."

Apparatus.
The Proctor Needle consists of a hollow cylinder containing a calibrated spring and plunger. Pressure is transmitted to the plunger and spring by means of a rod and handle. The rod is graduated to read resistance directly in pounds. A small sliding collar on the rod records the maximum resistance each time a reading is taken. A set of interchangeable needles, with flat ends and circular cross-sectional areas of 1/20, 1/10, 1/5, 1/3, 1/2, 3/4 and 1.0 square inch, respectively; are attached individually to the end of the movable plunger.

Calibration of Equipment.
The equipment should be calibrated before any tests are made, and at occasional intervals thereafter. This can be done by the following method:

Place a large needle on the end of the device. Set the beam of a platform scale to some definite reading; for example, 50#. Set the sliding collar to read "0" pounds on the rod. Set the needle on the platform of the scale and apply a slow gradual pressure until the beam begins to move showing that the exact pressure of 50# is being applied. Release the pressure and read the pounds pressure recorded on the rod. This reading should be 50# and will determine whether the top or the bottom of the sliding collar should be read. In some cases it may become necessary to choose one side of the collar to read for all tests and apply a correction factor. An average of at least four checks should be made. The above steps should be repeated using different readings on the scale.

Test Procedure.
The following tests are usually made on the specimen molded in the Proctor mold during the performance of the standard compaction test.

After each specimen has been molded, trimmed and weighed, the test is performed as follows:

1. Place mold containing specimen on the floor or suitable surface with the top side up. It is desirable to position the sample so the operator can stand over the mold to exert an even pressure on the test needle.

2. Select the proper size needle; the needle used should be of such size that the readings obtained on the Pressure Scale will be between 20 and 75. It may be necessary to first select the proper needle by trial, but with a little experience operators will be able to determine which needle to use by the apparent hardness of the soil.

3. Set the sliding collar to read "0" on the rod.

4. Holding the needle normal to the surface plane of the soil, force it into the soil at a rate of approximately 1/2 inch per second. The reading should be taken when the needle moves smoothly through the soil at about this rate without the need of additional pressure. The small penetration which occurs while the pressure is being built up to the maximum required is not taken into account.

5. Continue the pressure until the penetration reaches at least 3 inches. Then release the pressure and read the maximum pounds of pressure recorded on the rod by the sliding collar.

6. Take three or more needle readings with the proper size needle and average the results. The individual penetrations should be located away from the edge of the mold and so spaced that they will not interfere with one another.

7. Compute the penetration resistance in pounds per square inch for the average reading. This value is obtained by dividing the average number of pounds by the area in square inches of the needle being used. Record this value on the data sheet for compaction and resistance test under Form SCS-359, Items 6, 7 and 8, Figure 4-18.

8. Plot a curve of percent molding moisture versus Proctor Penetration resistance on the graph used for plotting the Proctor moisture-density curve, Form SCS-352, Figure 4-19.

The following procedure may be used for determining approximate moisture content in the field:

1. Select a representative sample of soil for which it is desired to know the approximate moisture content.

2. Break up the soil to where a majority of the lumps will pass the No. 4 screen.

3. Using the Proctor mold, compact either two or three layers of soil in the mold as described under the standard Proctor test. Choose the proper size needle and determine the Proctor penetration-resistance value in pounds per square inch as described above. An average of three or more readings should be used in obtaining this value.

4. Identify the soil being tested and plot the penetration-resistance value on the laboratory curve made for this soil.

5. Read down to obtain the approximate moisture content of the soil.

This procedure permits rapid testing of the moisture content of the soil, which must be checked for accuracy by the occasional drying of samples. The accuracy of the test will be dependent both upon the care with which it is performed and the ability of the inspector to identify the soils so as to know which curve to use in interpreting results. The presence of rocks or pebbles in the soil will cause a prohibitive loss in accuracy and, consequently, <u>the test should not be used</u> under such conditions. Sands or soils containing coarse granular particles may also provide misleading results. The <u>test is best adapted to uniform fine grained soil.</u>

Test No. S-10

Moisture Content Determination (Oven Method)

General.
The percent of moisture in a soil or any other material is the weight of moisture present in the sample expressed as a percent of the weight of the oven-dry sample when dried to constant weight at a temperature of approximately 105° C. (220°F.). The test described hereinafter has direct application to the moisture-density relations of soil, Test No. S-7, and may also be used in conjunction with field density tests No.'s S-2, S-3, S-4, and S-5. The moisture content of any soil or aggregate sample may be determined by this procedure.

Apparatus.
Equipment required for standard moisture determination includes the following:

1. Minimum of three moisture cans with covers (aluminum preferred).

2. A balance of at least 1000 gram capacity, sensitive to 1/10 gram.

3. Drying oven capable of maintaining a temperature of 105° C. to 115° C, (220° F. to 240° F.).

4. Standard laboratory thermometers.

Test Procedure.
After the moist soil sample has been taken from the mold, placed in the covered moisture can, weighed and weight recorded as specified under Test S-7, "Moisture Density Relations of Soils," the sample is then oven dried in the following manner:

1. The can containing the moist soil sample with lid is placed in the oven (with the lid removed) and dried to constant weight at a temperature between 105° C. to 115° C. (220° F. to 240°F.).

2. The length of time required to dry a given size sample to constant weight should be determined for any given drying procedure by the following methods:

   (a) Dry the sample for a length of time slightly less than that estimated to be necessary, cool and weigh.

   (b) Replace sample in oven and dry for additional one hour, cool, and weigh again.

   (c) Repeat this process until two successive weighings give the same weight within accuracy of the weighing device, showing that no additional moisture is being lost by further drying.

   (d) The time interval at which this constant was reached is chosen as the minimum length of drying time.

3. The container and lid with the oven-dried sample is removed from the oven, cooled and weighed, and the weight recorded under Item 12, Form SCS-359, Figure 4-18. The weight of moisture in the sample is computed by subtracting the dry weight of sample plus container from the wet weight of sample plus container, Item 11 minus Item 12, Figure 4-18.

4. The dry soil is then emptied out of the container and the container wiped clean. The empty container with cover is then weighed and weight recorded under Item 14, Figure 4-18. The oven dry weight of the soil sample is next computed, Item 12 minus Item 14, Figure 4-18, SCS-359.

Record all data for moisture determination on SCS-359 if information will be used for making compaction and penetration resistance report, otherwise Form SCS-531, "Moisture Content Determination," may be used (see Figure 4-20). The data may also be recorded on forms SCS-530A or SCS-530B, if the moisture information is used in the field moisture-density determinations.

Any soil that has been subjected to heat above 105° C. (220° F.) should not be subsequently used in making other soil tests. The test may have changed the character of the clay present and thereby affected the characteristics of the soil.

Calculations:

The moisture content of the soil may be calculated as follows:

$$M = \frac{Ww - Dw}{Dw - Tw} \times 100$$

M = percentage of moisture in the sample.

Ww = weight of can and wet sample.

Dw = weight of can and dry sample.

Tw = weight of sample container.

SCS-531
(REV. 11-19-64)

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

MOISTURE CONTENT DETERMINATION
Summary Data Sheet

Oven Drying Method ____
Quick Method
Pan Drying Method
Alcohol Drying Method
____ Method

Kind of Material ____

Location ____ Owner ____

Watershed ____ Sub-Watershed ____ Site No. ____

Contract No. ____ Contractor ____

Test No.	Date of Test	Location of test: Structure or Station & Offset	Elev-ation	WW	DW	TW	Per Cent Moisture Content: Oven Method	Per Cent Moisture Content: Quick Method	Per Cent Moisture Content: Correct. Factor	Per Cent Moisture Content: Corr'd Moisture	Tested By

$$\text{Percent Moisture} = \frac{(WW-DW)}{(DW-TW)} \times 100$$

Where: WW = Wet Wt. Sample + can.
DW = Dry Wt. Sample + can.
TW = Tare Wt. of can.

Figure 4-20

Test No. S-11

Moisture Content Determination - Quick Dry Method

General.

The following procedure represents a method of determining the moisture content of the minus #4 fraction of a soil in approximately 10 to 30 minutes for conditions when quick results are required. The results obtained by this test procedure will be subject to slight errors, but should be within the limits of accuracy required for the field control of moisture content for most soils. When the percent loss by ignition exceeds 5 percent, this rapid drying test procedure should not be used.

Apparatus.

The following equipment is required for the test:

1. Source of heat producing high temperature, such as a blowtorch, gasoline stove, or a butane gas burner.

2. A balance having a capacity of at least 25 pounds, sensitive to 0.01 pound, or a balance of at least 1000 gram capacity sensitive to 0.1 gram.

3. No. 4 standard sieve.

4. Heavy cast iron skillet or pan of 10 inch to 12 inch diameter.

5. Suitable container with airtight cover.

6. Brass wire brush for cleaning equipment.

7. Large spoon for stirring sample while in process of drying.

Calibration of Test Procedure.

The percent moisture in a soil is expressed as the weight of moisture divided by the weight of oven dry soil when dried to constant weight at approximately 105° C. (220° F.). When the rapid drying method is used, there may be a small amount of combustible material which would not be burned at 105° C. but will burn at higher temperatures. If this were not recognized, this loss of organic matter, etc., by ignition at high temperatures would show up in the calculations as a loss in moisture content, thus creating an error in the result.

For this reason it is necessary that each different type of soil be calibrated to determine the percent loss by ignition in the rapid drying test, thus establishing a correction factor which may be applied to subsequent quick drying tests on the soil. The calibration procedures are as follows:

1. Adopt a procedure to be used in the field for making the rapid drying test for percent moisture. This means that all the conditions should be kept approximately the same for all tests made by this procedure, which include size of sample, method of stirring, drying temperature, size of flame, distance of container from flame, length of drying period, etc. Preliminary tests should be made to insure that the test procedure will dry the moist sample to constant weight.

2. Select a minimum of three representative samples of the soil to be calibrated. These samples may or may not have the same moisture content but each sample should have some moisture present.

3. Carefully quarter each sample so as to obtain two representative portions of approximately the same size. The size of these portions will depend upon the maximum size of soil particles and the sensitivity of the weighing device.

4. Accurately weigh each of the six portions immediately after the samples have been quartered.

5. For each of the three original samples, dry one of the portions to constant weight in a controlled oven at a temperature range between 105° C. to 115° C. (220° F. to 240°F.). Dry the other portion of each sample by the rapid drying procedure that will be used for field control.

6. Cool and weigh each of the six portions and calculate the percent loss:

$$\text{Percent Loss} = \frac{WW - DW}{DW - TW} \times 100$$

Where WW = Wt. of wet soil and container.

DW = Wt. of dry soil and container.

TW = Tare weight of container.

7. For each sample the percent loss by rapid drying minus the percent loss at 105° C. equals percent loss by ignition. <u>The average percent loss by ignition for the three samples must be subtracted from all future moisture calculations made for this type soil, when dried by the specific rapid drying procedure</u>.

<u>Test Procedure.</u>
The procedure for making the quick drying test in the field is as follows:

1. The sample should be transported from the point of collecting the sample to the place of performing the test in an air tight container.

2. The soil sample, weighing at least 1 pound or approximately 500 grams, is passed through the No. 4 sieve and placed in the skillet or pan and accurately weighed. This weight is recorded as the wet weight of the soil sample and container (WW).

3. The pan with the soil sample is then placed over a hot flame to dry out the moisture. The sample of soil should be stirred frequently while being dried.

4. When the soil has dried, it is allowed to cool and is accurately weighed again. This weight is recorded as the dry weight of the soil and container (DW).

5. The difference between the WW and DW weights is the weight of moisture driven from the soil plus any loss by ignition.

6. The dry soil is emptied from the pan, the pan cleaned and weighed, and this weight is recorded as the tare weight (TW).

7. Calculate: $\text{Total \% loss} = \frac{WW - DW}{DW - TW} \times 100$

8. Calculate percent moisture in the soil:

   % moisture = Total % loss - % loss by ignition

   This percent loss by ignition is the value determined for the given soil in the calibration test described above.

Samples containing large amounts of #4 size material may require that the moisture determination be made also on the coarse fraction or on a composite of all the samples. Often a larger sample will be used when testing these materials.

Recording Data.
Form SCS-531 entitled, "Moisture Content Determination - Summary Data Sheet" Figure 4-20 may be used for recording the results of this test.

Test data may also be reported on Forms SCS-359, 530A and 530B if the moisture content is required to complete the test.

Figures 4-21A, B, C and D illustrate the major operations in performing the quick drying test.

A. - Obtaining sample for moisture determination.

B. - Obtaining and recording wet weight of sample and pan.

C. - Drying sample by quick drying method.

D. - Obtaining and recording dry weight of sample and pan.

Figure 4-21

Test No. S-12

Moisture Content Determination - Alcohol Method

General.

This test may be used for determining the moisture content of the minus #4 fraction soil samples under conditions which require quick results. This method will give satisfactory results for most soils, however, when the percent loss by ignition exceeds 5 percent this quick test procedure should not be used.

Apparatus.

The following equipment is required for the test:

1. Burning cup - an alcohol burning cup with perforated bottom and tight cover.

2. Filter paper - a supply of filter paper to fit burning cup.

3. Balance - a balance of 100 g. capacity, sensitive to 0.1 g.

4. Stirring rod - a glass or metal stirring rod.

5. Alcohol - supply of wood or grain alcohol of the grade manufactured for burning purposes.

Test Procedures.

1. Transport sample from the point of collection to the test site in an air tight container.

2. Select approximately 30 g. (wet weight) of material passing the No. 4 sieve for the test.

3. Determine the tare weight of the burning cup with filter paper in place.

4. Place the wet sample in the cup and determine the weight of the sample plus burning cup.

5. Place the cover for the cup in an inverted position beneath the cup to form a saucer, and stir into the soil sufficient alcohol to produce a thin mush or slurry. Allow the stirring rod to dry and brush the clinging soil particles into the cup.

6. Ignite the alcohol in the cup and saucer and allow to burn off. In some instances it may be beneficial to continue stirring the sample while burning.

7. Allow sample to cool about one minute after burning.

8. Repeat the process of adding alcohol, stirring and burning three (3) times.

9. After the last burning, determine the weight of the dry soil plus cup.

Calculations.

The moisture content in percent is calculated as follows:

$$\text{Total \% loss} = \frac{WW - DW}{DW - TW} \times 100$$

$$\text{Percent Moisture } M = \text{Total \% loss} - \text{\% loss by ignition.}$$

Where:

WW = Weight wet soil plus cup and filter.
DW = Weight of dry soil plus cup.
TW = Weight of cup and filter.

Note: The percent loss by ignition correction may be determined by the method outlined for "Calibration of Test Procedures" contained in Test No. S-11.

Recording Data.

Test data may be reported on Forms SCS-530A or 530B, if the moisture content is used to complete the density tests. Form SCS-531, Figure 4-20, may also be used to record the test results.

Test No. S-13

Moisture Content Determination - Speedy Moisture Meter

General.

The following procedure presents a method for determining the moisture content of a soil, or sand aggregate material by a chemical reaction using calcium carbide as a reagent.

The principal involved is that a given quantity of moisture will react with calcium carbide to produce a specific volume of gas (acetylene). The gas pressure is read on a gauge located in the base of the pressure vessel. The gauge is calibrated to read in percent moisture based on the wet weight of the sample. See Figure 4-22.

The moisture tester is manufactured in two sizes, one for a sample of 6 grams and the other for 26 grams.

There are advantages in using the large size, to improve the accuracy in testing the full range of soil types.

Apparatus.

1. Moisture tester equipment, complete with tared scale for weighing the sample, a small scoop for measuring the calcium carbide and a table to convert percent moisture to dry weight basis.

2. Supply of carbide.

3. Number 4 standard sieve.

4. Scales, oven, sample cans and other laboratory items required for performing standard oven dry moisture determinations.

Calibration Curve.

To secure a higher degree of accuracy, it is recommended that the results of the moisture meter be used in conjunction with a calibration curve that is representative of the sample material and the tester being used. To prepare the calibration curve, a number of tests are made on the soil material using a fairly complete range of moisture content. The moisture content of each sample (more than one check is desirable for a sample) should be tested with the moisture meter and also by the standard oven dry method, (Refer to Test No. S-10). The results of the oven dry moisture content percent versus moisture meter direct reading (percent) should be plotted as a calibration curve. This curve is used in converting the meter reading to true moisture content.

Laboratory tests and field results indicate that there is a conversion factor for the different types of soil, and there also may be slight variations in the meter equipment.

Figure 4-22 - The speedy moisture meter and accessories

Therefore, a calibration curve should be prepared for each site or change in borrow material and control maintained on the results of the meter, by making oven dry tests on the same materials as tested by the meter. The frequency for making the oven tests should be governed by the accuracy of the meter reading as compared to the calibration curve. If the results are close, fewer oven tests may be required, or if the established calibration curve is not giving satisfactory results, more oven samples may have to be run and the curve replotted.

The carbide moisture meter has proven to be reasonably accurate for a quick field test providing proper procedures are used in conducting the tests.

Test Procedures.

The test procedure specified by the equipment manufacturer should be carefully adhered to:

For the 26 gram size meter, the procedure is about as follows:

1. Place three measures (approximately 22 grams) of calcium carbide and two (2) 1-1/4 in. steel balls (wt. 0.4 lb.) in the large chamber of the meter.

2. Using the tared scale, carefully weigh a 26 gram sample of soil (half size, 13 gr. sample may be used if moisture content exceeds the limit of the pressure gauge).

3. Place soil sample (passing No. 4 sieve) in the cap; then with pressure vessel in a horizontal position, insert the cap in the pressure vessel and tighten clamp to seal cap to unit.

4. Raise meter to a vertical position so that the contents from the cap fall into the pressure vessel.

5. Holding the meter horizontal, rotate the device for 10 seconds, so that the steel balls are put in orbit around the inside circumference, and then rest 20 seconds. Repeat shake-rest cycle for a total of 3 minutes. Do not allow the steel balls to fall against and damage either the cap or orifice leading to the dial. (Allow about three (3) minutes after mixing cycle for total reaction to take place.)

6. Read pressure gauge and determine moisture content of the wet sample.

7. Using meter reading determine corrected moisture content of sample from the calibration curve.

Recording Data.
Test results used in conjunction with inplace density determinations may be recorded on Form SCS-530A, Item 8 (Items 1-7 do not apply).

Moisture determinations made for other purposes or on other materials may be recorded on Form SCS-531.

Note:
It is very important that caution is exercised to prevent overloading of the test apparatus. Serious damage to the equipment can result, and for very wet sample material such as organic soils, pressures can develop that will rupture the equipment and possibly cause bodily harm to the operator.

Test No. S-15

Procedure for Determining Percent Absorption and Bulk Specific Gravity of Rock Fraction

General.
This method of test conforms to ASTM Designation C-127. The procedure is also duplicated by AASHO Designation T-85, or Fed. Test Method 209.0.

Sample. Obtain a representative sample of the rock from material to be used in the fill or from test material removed from the fill. Sample should be protected from drying until prepared for test.

Moisture Content of Rock (M_r).

1. Remove all soil adhering to the surface of the rocks, by rubbing or brushing (do not wash).

2. Place rock in can with cover and weigh immediately.

3. Place rock plus can in controlled drying oven and dry to constant weight at a temperature of 100° - 110° C. (212° - 230°F).

4. Following standard procedure outlined in Test No. S-10 for moisture content determination. Form SCS-531 may be used to record data or the percent moisture should be recorded in column (14), Form SCS-358 when required for Test No. S-14.

Bulk Specific Gravity of Rock (Gm).
Method A.--For rock that does not disintegrate or break down when immersed in water.

1. Wash rock sample.

2. Immerse rock in water at 15° to 25° C. until completely saturated. Saturation will require 24 hours if the dried specimen used for moisture determination is used. A period of 1 to 2 hours should be sufficient to saturate specimen at natural moisture.

3. Remove from water and roll in absorbent cloth until visible film of water is removed (surface will still appear damp).

4. Determine weight of sample in air.

5. Determine the volume of the sample by:

   (a) Placing sample in wire basket or suspend by string and determine weight submerged in water, as shown in sketch. It is also necessary to determine the weight of the submerged wire basket or string in order to obtain the correct weight of submerged rock.

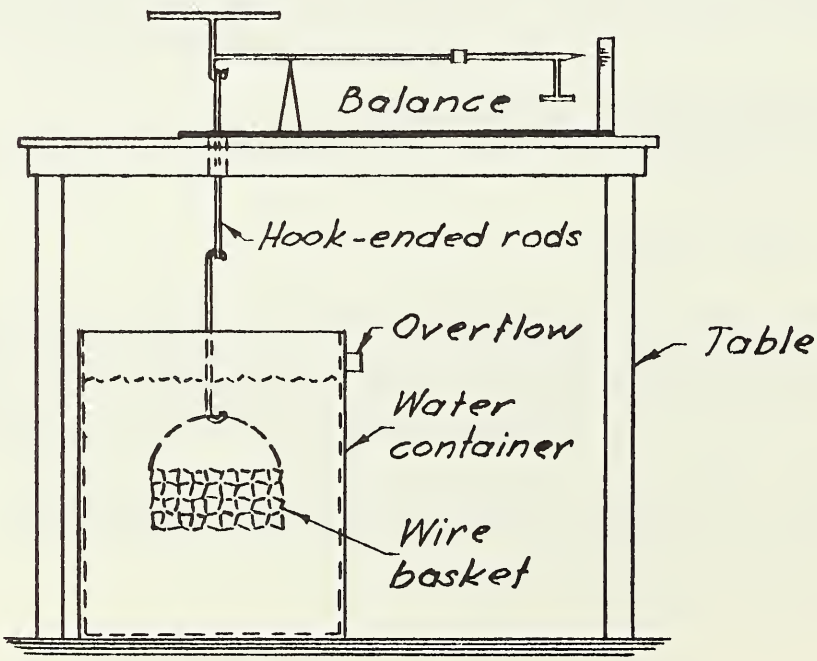
   (b) Placing the sample in siphon can or graduated cylinder and measure the volume of water displaced.

6. Dry rock in oven and determine dry weight, if not dried before saturation in step (2).

7. Record all data and complete computations on Form SCS _____, Figure 4-26 as follows:

   (a) Bulk specific gravity-oven dry (Gm).

$$Gm = \frac{\text{Oven dry weight}}{\text{Volume of sample when saturated}}$$



Sketch showing equipment setup for determining submerged weight of rock

BULK SPECIFIC GRAVITY AND MOISTURE DETERMINATION
(ROCK, GRAVEL, SHALE, SOIL CLODS, ETC.)

Location ______________________ Date ______________

Watershed ____________ Sub-Watershed ____________ Site ________

Contract No. ____________ Contractor ______________________

Tested by __________ Computed by __________ Checked by __________

MOISTURE DETERMINATIONS

(1)	Moist Weight of Rock + Container	________	gm
(2)	Dry Weight of Rock + Container	________	gm
(3)	Weight of Container	________	gm
(4)	Dry Weight of Rock	________	gm
(5)	% Moisture [(1) - (2)] ÷ (4) x 100	________	%

Bulk Specific Gravity - Method A - Hard, Sound Rock or Gravel

(6)	Wt. of Basket (Container) or Cord in Air	________	gm
(7)	Wt. of Basket (Container) or Cord in Water	________	gm
(8)	Wt. of Sample (Natural Moisture) + Basket in Air	________	gm
(9)	Wt. of Sample (Natural Moisture) in Air = (8) - (6)	________	gm
(10)	Wt. of Sample (Saturated) + Basket in Air	________	gm
(11)	Wt. of Sample (Saturated) in Air = (10) - (6)	________	gm
(12)	Wt. of Sample (Saturated) + Basket in Water	________	gm
(13)	Wt. of Sample (Saturated) in Water (12) - (7)	________	gm
(14)	Vol. of Sample by Weight = (11) - (13) or Vol. Measured	________	cm^3
(15)	Bulk Specific Gravity (Oven Dry) G_m = (4) ÷ (14)	________	
(16)	Bulk Specific Gravity (Natural Moisture) G_{mm} = (9) ÷ (14)	________	
(17)	Bulk Density - Oven Dry (γ_d) = (15) x 62.4	________	p.c.f.
(18)	Bulk Density - Natural Moisture (γ_m) = (16) x 62.4	________	p.c.f.

Bulk Specific Gravity - Method B - Materials that Disintegrate in Water.

(19)	Wt. of Specimen in Air	________	gm
(20)	Wt. of Specimen + Wax in Air	________	gm
(21)	Wt. of Wax in Air = (20) - (19)	________	gm
(22)	Wt. of Specimen + Wax in Water	________	gm
(23)	Vol. of Specimen + Wax by Wt. = (20)-(22) or Vol.Measured	________	cm^3
(24)	Vol. of Wax = (21) ÷ Specific Gravity of Wax	________	cm^3
(25)	Vol. of Specimen (23) - (24)	________	cm^3
(26)	Bulk Specific Gravity (Natural Moisture) = (19) ÷ (25)	________	
(27)	Bulk Specific Gravity(Oven Dry) G_m = (26) ÷ [1 + (5)/100]*	________	
(28)	Bulk Density - Natural Moisture = (26) x 62.4	________	p.c.f.
(29)	Bulk Density - Oven Dry = (27) x 62.4	________	p.c.f.

* [1 + (5)/100] is the number 1 and not (1) in these computations.

Figure 4-26

(b) Bulk specific gravity - moist or natural moisture (Gmm).

$$Gmm = \frac{\text{Moist Weight}}{\text{Volume of sample when saturated}}$$

(c) Bulk specific gravity - saturated surface dry (Gms)

$$Gms = \frac{\text{Saturated surface dry weight}}{\text{Volume of sample when saturated}}$$

Bulk density - dry (γ d) = Gm x 62.4 (lbs/ft.^{3})

Bulk density - moist or natural (γ m) = Gmm x 62.4 (lbs/ft.^{3})

Bulk density - saturated (γ s) = Gms x 62.4 (lbs./ft.^{3})

Method B.--For rock (or soil lumps) that disintegrate in water.

Specimen to be tested should be at least 2" in diameter or cubed in size; solid and nonfractured with smooth surfaces. (The accuracy of the test may be augmented by increasing the size of the test sample.)

1. Remove all loose soil from the surface of each specimen to be tested by brushing, using air, or other methods.

2. Determine the weight of each specimen.

3. Waterproof each specimen by dipping in melted wax. Be sure that the waterproof coating is positive. Wax should be at a temperature barely above the melting point. Wax that is too hot has a tendency to penetrate the rock.

4. Determine the weight of each sample after coating with wax.

5. Determine the volume of waxed specimen by measuring the water displaced in a graduated cylinder or by determining the submerged weight using a siphon can as given in Method A.

6. Strip wax from specimen, then crumble the test sample and dry in oven to determine moisture content.

7. Record all data and complete computations on Form SCS-543, Figure 4-26, as follows:

   (a) Bulk specific gravity - oven dry (Gm).

$$Gm = \frac{\text{Oven dry weight}}{\text{Volume of sample}}$$

   (b) Bulk specific gravity - natural moisture (Gmm).

$$Gmm = \frac{\text{Moist (Natural) weight}}{\text{Volume of Sample}}$$

Absorption.

The percentage of absorption for a given sample may be calculated as follows:

$$\text{Absorption \%} = \frac{B - A}{A} \times 100$$

Where:

A = Weight oven dry sample in air

B = Weight of saturated surface-dry sample in air.

Test No. C-1

CONCRETE AND CONCRETE MATERIAL

Standard Method of Sampling Fresh Concrete

General.
The standard procedure for sampling fresh concrete is covered in ASTM Designation: C-172, and AASHO Designation T-141, "Sampling Fresh Concrete." Principal features of the test method are listed below:

Size of sample.--The size of the sample should be adequate to make the strength, slump and air entrainment tests as required. Fresh sample material is used for each separate test. (Do not reuse material from another test). The sample should consist of not less than one cubic foot when it is to be used for strength tests. Smaller samples may be used for routine air content and slump tests.

Procedure for sampling.--Every precaution must be taken to secure samples that are representative of the concrete being sampled. When sampling from revolving drum truck mixers or agitators, the sample is taken at two or more regular intervals throughout the discharge of the entire batch, except that a sample should not be taken at the beginning or end of discharge. Sampling may be done by repeatedly passing a receptacle through the entire discharge stream (see Figure 4-27A).

Remixing sample.--The composite sample is transported to the place where test specimens are to be molded or where other tests are to be made and remixed with a shovel the minimum amount to insure uniformity. The sample should be protected from sunlight and wind during the interval before using, which normally will not exceed 15 minutes.

Note:
An exception to the standard sampling procedure C-172 is provided for in the specifications to permit sampling for slump and air content at any time during the discharge of the batch. The inspector, at his discretion, may also make a single test cylinder from such a sample. Since three test cylinders are required for a strength test, two additional cylinders should be made either from the same or other individual samples, as desired. This deviation is provided in order that the testing procedure will reveal any deterioration of the mix during an extended period of discharge.

A. - Taking portion of sample from mixer.

B. - Removing the mold from the concrete.

C. - Determining the slump.

Figure 4-27

Test No. C-2

Standard Method for Slump Test of Portland Cement Concrete

General.

The standard procedure for making the slump test is presented in ASTM Designation: C-143, AASHO Designation T-119, and Fed. Spec. SS-R-406, Method 232.0, "Test for Slump of Portland Cement Concrete."

Apparatus.

Equipment required to perform the slump test includes the following:

1. Galvanized metal mold in the form of a frustum of a cone with 8 inch diameter base, 4 inch diameter top and 12 inches high. The base and top are open and parallel to each other and at right angles to the axis of the cone. The mold should be provided with foot pieces and handles as shown in Figure 4-27B.

2. Tamping rod, 5/8 inch diameter, 24 inches long, with one end rounded.

3. Supplementary equipment used in performing this test includes a bucket for sampling the concrete, large mixing pan, scoop, shovel or trowel, and a rule for measuring the slump.

Test Procedure.

Major steps to be followed in the test are as follows:

1. Three samples of concrete are taken from the mixer or agitator during discharge and remixed in the manner specified for sampling fresh concrete. (Refer to Test C-1).

2. The mold should be dampened and placed on a firm, flat nonabsorbent surface. The fresh concrete is placed in the mold in 3 layers, each approximately one-third the volume of the mold. One-third of the volume of the mold fills it to a depth of 2-5/8 inches and two-thirds of the volume fills it to a depth of 6-1/8 inches. The top layer should be heaped above the top of the mold before rodding is started.

3. Each layer is rodded 25 strokes in a uniform manner over the cross section of the mold. The rod should penetrate just into the underlying layer.

4. After the top layer has been rodded the surface of the concrete is struck off flush with the top of the mold by means of a screeding and rolling motion of the tamping rod.

5. The mold is then removed immediately by raising it carefully in a vertical direction (see Figure 4-27B).

6. The slump is measured immediately by determining the difference between the height of the mold and the height at the vertical axis of the specimen to the nearest 1/4 inch (see Figure 4-27C). The slump is recorded in terms of inches of subsidence of the specimen during the test. The entire operation from the start of the filling through removal of the mold should be carried out without interruption and completed within an elapsed time of about 1-1/2 minutes.

7. After the slump has been measured the side of the concrete frustum may be tapped lightly with the tamping rod. The behavior of the concrete under this treatment is a valuable indication of the cohesiveness, workability and placeability of the mix. A well proportioned workable mix will gradually slump to lower elevation and retain its original identity, whereas a poor mix will crumble, segregate, or fall apart.

Recording Data.

The location in the structure where the batch of concrete being sampled was placed should be recorded in the Job Diary for future reference together with the slump measurement. Also, record batch number if transit truck is used. Slump tests made in conjunction with the molding of test cylinders are recorded on Form SCS-59, "Data on Concrete Test Specimens" under heading slump, in inches (see Figure 4-29, Test C-3).

Test No. C-3

Standard Method of Making and Curing Concrete Compression Test Specimens

General.

The standard procedure for making and curing compression and flexure test specimens in the field is covered in ASTM Designation: C-31, AASHO Designation T-23, "Making and Curing Concrete Compression and Flexure Test Specimens in the Field."

Apparatus.

Equipment used in performing this test for compression test specimens includes the following:

1. Molds for compression test specimens of cylindrical shape made of nonabsorbent material, 6 inches inside diameter by 12 inches high. Metal molds should be equipped with metal base plates which, when assembled, will be watertight.

2. Tamping rod, 5/8 inch diameter, 24 inches long with rounded end.

3. Supplementary equipment used in performing this test includes a bucket for sampling the concrete, large mixing pan, scoop shovel, trowel and glass or metal plate to cover top of molded cylinder.

Test Procedure.

Major steps to be followed in making and curing the test specimens are as follows:

1. Three test specimens are made for each proposed compression test.

2. The molds should be placed on a firm, level area to insure stability during the forming operation (see Figure 4-28A). The interior surface of metal molds should be oiled prior to receiving concrete.

3. The test specimen is formed by placing the concrete in the mold in three approximately equal layers. The material should be uniformly distributed as it is placed in the mold (see Figure 4-28B).

4. Each layer is then rodded with 25 strokes of the tamping rod distributed uniformly over the cross section of the mold with the rod penetrating into the underlying layer. Where voids are left by the tamping rod the sides of the mold may be lightly tapped to close the voids.

5. After the top layer has been rodded, the surface of the concrete should be struck off with a trowel level with the top of the mold. The top is then covered with a glass or metal plate to prevent evaporation (see Figure 4-28C).

6. During the first 24 hours all test specimens should be kept in a storage box or other location where the temperature can be controlled between 60° to 80° F. (see Figure 4-28D).

7. Test specimens made to check the adequacy of the laboratory design for strength, or as a basis for acceptance, are removed from the molds at the end of 24 hours and stored in a moist condition at a temperature of 73.4 $\pm$ 3.0° F. until the time of test. If storage is in water a saturated lime solution should be used.

8. Test specimens for determining when a structure may be put in service are removed from the molds at the end of 24 hours and stored in the structure as near to the point of placement of the material represented by the sample as possible, and receive the same protection from the elements as is given to the portions of the structure which they represent. Field control specimens should be protected from injury while being stored on the site. For 28 day tests, the specimens are sent to the laboratory not more than 7 days prior to the time of test. For other periods of test the specimens will be kept in the field at least three-fourths of the test period. While in the laboratory the specimens are kept at laboratory temperature until 24 to 48 hours before testing. During this final period they are immersed in water at laboratory temperature.

Recording Data.

A complete record of location of placement of the material being tested, the total section represented by the test, the truck batch number, and the field concrete test report number should be recorded in the Job Diary.

Form SCS-59, "Data on Concrete Test Specimens" is prepared for each set of compression test cylinders (see Figure 4-29). These reports should be maintained in the project office file.

The concrete test specimen report should be numbered consecutively throughout the duration of the contract, and the field data recorded as the specimens are molded.

It is desirable to submit two copies of SCS-59 to the testing laboratory for their use at the time of making the compression tests. One completed signed copy should be returned by the laboratory to the government representative immediately after completing the test.

If SCS-59 is not furnished to the testing laboratory, the test result data should be copied from the laboratory report onto the field SCS-59 report form to complete the record for each test specimen.

A. *Concrete sample for molding test cylinders.*

B. *Placing and rodding concrete in three equal layers.*

C. Numbering test specimens.

D. *Protecting molded specimens. Note cloth cover and access to water.*

Figure 4-28

SCS-59
(Rev. 11-19-64)

U.S. Department of Agriculture
Soil Conservation Service

REPORT ON CONCRETE TEST SPECIMENS

FIELD DATA

PROJECT

PROJECT	CONTRACT NO.	REPORT NO.
Marsh-Kellogg WPP	12-10-040-195	6

SITE	STRUCTURE
Marsh Creek Dam	Principal Spillway
WATERSHED	**SUBWATERSHED**
Marsh-Kellogg	Marsh Creek

SPECIMENS

NO. OF SPECIMENS: 6
TYPE: ☒ CYLINDERS ☐ BEAMS ☐ CORES INCHES, DIAM.

CONCRETE CLASS	SPECIFICATION MIX NO.	VOLUME OF BATCH	TYPE MIX
B	2	1.0 CU. YD.	☒ JOB ☐ READY

LOCATION IN STRUCTURE: Base of drop inlet riser

DATE PLACED	DATE EXTRACTED (CORES)	DATE SHIPPED	PREPARED BY
5-9-61	—	5-10-61	B. B. Brown

JOB MIX

MATERIALS	BATCH SCALE WEIGHTS (POUNDS)	DESCRIPTION
CEMENT	564.0	BRAND: Permanente; ASTM TYPE: I
COARSE AGGREGATE	2020.0	MAX. SIZE: 1.5 INCHES; MOISTURE: 1.6 %; SOURCE SYMBOL: C-1
FINE AGGREGATE	1400.0	FIN. MOD.: 2.85; MOISTURE: 4.2 %; SOURCE SYMBOL: A-2
WATER	312.0	Temperature 61°F
ADMIXTURE	None	TYPE: ; BRAND:

MIXING TIME: 10 MIN.
REMARKS: Air temperature 87°F.

READY MIX

SOURCE AND/OR PLANT LOCATION:
LOAD TICKET NUMBER:

SUMMARY OF LABORATORY DATA

FIELD SPECIMEN NUMBER	SLUMP	AIR CONTENT	LABORATORY SPECIMEN NUMBER	DATE RECEIVED	DATE TESTED	AGE (DAYS)	STRENGTH (LBS./SQ. IN.)	TYPE OF BREAK
31	4"	4%	1264	5-10-61	5-16-61	7	2406	Normal
32	4"	4%	1265	5-10-61	5-16-61	7	2375	"
33	4"	4%	1266	5-10-61	5-16-61	7	2479	"
34	3½"	5%	1267	5-10-61	6-6-61	28	3128	"
35	3½"	5%	1268	5-10-61	6-6-61	28	3015	Diagonal
36	3½"	5%	1269	5-10-61	6-6-61	28	3300	Normal

METHOD OF CURING	NAME OF LABORATORY
Fog room @ 75°F.	Bay Testing Lab. Richmond, Calif.
METHOD OF CAPPING	
Sulphur Compound	

Make in triplicate
Original and 1 c.c.
to Testing Lab.

Figure 4-29

Standard Method of Test for Slump of Portland Cement Concrete - Kelley Ball Method

General.

The slump of concrete by the Kelley ball method is a procedure for determining the consistency of fresh concrete. This method of test is covered in ASTM Designation C-360 and AASHO Designation T-183, "Ball Penetration in Fresh Portland Cement Concrete." This method is quick and has application for certain types of work. It may be used as an indicator of the slump. Results of this test should be verified by the slump cone, Test C-2, if acceptance of the concrete is in question.

Apparatus.

The Kelley ball apparatus consists of a metal 6 inch diameter hemispherical tip which is machined to a special finish. The penetrator is equipped with a graduated shaft, with handle attached, and the total assembly weighs 30#. The ball assembly is supported in a vertical position by a stirrup shaped frame to guide the handle and weight, and to serve as reference for measuring the depth of penetration. Each foot of the supporting frame has a minimum bearing area of 9 sq. in. and the distance between feet is 9 inches. The graduations on the handle shaft are in increments of 1/4 inch. The top edge of the yoke or shaft support should coincide with the zero mark on the graduated handle when the apparatus is rested upon a plane solid surface.

Test Procedure.

The Kelley ball slump test may be made on concrete in a wheelbarrow, buggy or after it has been deposited in the forms, or on the subgrade. The minimum depth of concrete should be not less than three times the maximum size aggregate, but in no case less than 8 inches. The minimum horizontal distance from center of handle to the nearest edge of the level surface on which the test is to be made should not be less than 9 inches.

The concrete is tested as it comes from the mixer. For a test about 12 square inches of the surface of the concrete should be prepared to a smooth and level condition by the use of a small wood float, working the surface as little as possible to avoid mortar layers. Do not tamp, vibrate or consolidate in any way, or permit vibration adjacent to the test area.

Set the base of the apparatus on the leveled concrete surface, with the handle in a vertical position and free to slide through the frame. Lower the weight to the surface of the concrete and release slowly. After the weight has come to rest, read the penetration to the nearest 1/4 inch (see Figure 4-30A). Take a minimum of three readings spaced not closer than 10" to the location of the previous test. If check readings are not obtained, additional tests may be required.

The penetration of the ball in inches is equal to one half the slump as measured by the standard slump cone.

Accuracy is impared if the surface of the Kelley ball is roughened by dents, scratches, or adhering mortar.

Recording Data.

The penetration should be recorded in the Job Diary, indicating the location in the structure the concrete was placed. The transit truck batch number, and the average of the three or more penetration readings which agree within one (1) inch. All readings should be reported to the nearest 1/4 inch.

Test No. C-5

Standard Method of Test for Air Content of Freshly Mixed Concrete-By the Pressure Method

General.

This method of test covers the determination of the air content of freshly mixed concrete based on the change in volume with a change in pressure. A volume of air at a certain initial pressure is allowed to expand into a container of fresh concrete, compressing the entrained air voids. The reduction in pressure, which may be read directly on a gage, indicates the percentage of air voids in the concrete. This type of equipment is not affected by changes in barometric pressure.

The method of test is outlined in ASTM Designation C-231 and AASHO Designation T-152, "Air Content of Freshly Mixed Concrete by the Pressure Method."

Apparatus.

1. A metal base container with flanged top sufficiently rigid to make a pressure tight container of accurate volume and of adequate size to hold a representative sample of concrete.

2. A cover designed to be attached to the base of the container so as to provide a pressure tight assembly. The cover to be fitted with an air chamber, and a pump for supplying air pressure to the air chamber; a valve for releasing air contained in the air chamber into the sample container; a by-pass valve connected to the container which will release air directly to the atmosphere; and a pressure gage with adequate range. Figure 4-30B and C illustrates the type of equipment used for this test.

3. Appropriate tools for placing and consolidating the sample.

Calibration of Testing Equipment.

The procedure for calibration will vary depending on the design of the apparatus. The manufacturers' instructions should be followed in doing any necessary calibration or adjustment for satisfactory operation of the equipment.

Procedure for Determining Air Content of Concrete.

1. Fill the base container with a representative sample of the concrete in about three equal layers. Rod each layer of concrete with 25 strokes of the tamping rod evenly distributed over the cross section. After rodding each layer, the outside of the container should be tapped sharply 10 to 15 times with the rubber mallet to eliminate cavities left by rodding. No large air bubbles should appear on the surface of the rodded layer.

   Rodding of the second and third layers should be restricted in depth to just reach the surface of the previously placed layer.

Slightly overfill the container on the third layer and after rodding remove the excess by sliding the strike off bar across the top of the flanged container in a sawing motion to leave container level full.

2. Clean the flanges of the cover assembly and the sample container, and clamp cover in place with the operating and bleeding valves open. The operation of the valves and sequences of adding water and air pressure are performed in accordance with the manufacturers' instructions.

   Care must be exercised that water is not permitted to enter the air chamber and that the air pressure in the air chamber is properly adjusted to the initial mark before releasing the air pressure into the concrete chamber.

3. After the concrete sample is subjected to air pressure, and the gage has stabilized (tap gage lightly for more correct result) the percent of air contained by the sample is read direct on the dial.

Recording Data.

The location in the structure where the batch of concrete being sampled was placed; the batch number and the percent of air entrainment should be recorded in the job diary. When test is made in conjunction with the molding of test cylinders, the percent of air content is recorded on Form SCS-59, "Data on Concrete Test Specimens" under air entrainment, percent (refer to Figure 4-29).

Kelley ball equipment for testing slump of fresh concrete.

Air meter for testing entrained air content of fresh concrete (meter assembled)

Air indicator vial for testing entrained air content of fresh concrete mortar

Air meter lid removed for placement of concrete sample

Figure 4-30

Air Content of Freshly Mixed Concrete - by the Volumetric Method

General.

This method of test covers the procedure for determining the air content of freshly mixed concrete containing any type of aggregate.

The test procedure is outlined in detail in ASTM Designation C-173.

Apparatus.

1. An air meter consisting of a bowl and a top section conforming to the following requirements:

   Bowl - The bowl shall be constructed of machined metal of sufficient thickness to withstand field use. The bowl shall have a diameter equal to 1 to 1.25 times the height and constructed with a flange at or near the top surface. The capacity of the bowl shall be not less than 0.20 cubic feet.

   Top Section - The top section shall be constructed of machine metal, sufficiently rigid to withstand field use. The top section shall have a capacity approximately equal to the bowl and equipped with a flexible gasket and clamps to attach to the flange on the bowl to make a water tight connection. The top section shall be equipped with a glass-lined or transparent plastic neck, graduated in increments not greater than 0.5 percent from 0 at the top to 9 percent, or more, of the volume of the bowl. The upper end of the neck shall be threaded and equipped with a water tight screw cap.

   Funnel - A metal funnel with a spout of length and size that may be inserted through the neck of the top section and extend to a point just above the bottom of the top section. The discharge end of the spout should be constructed so that when water is added there will be a minimum disturbance of the concrete.

   Tamping Rod - A round, straight steel rod, 5/8 inch in diameter by 24 inches in length, having one end rounded to a hemispherical tip of 5/8 inch diameter.

   Strike-Off Bar - A steel bar approximately 1/4 inch by 1 inch, 18 inches long.

   Measuring Cup - A metal cup having a capacity equal to 1.0 percent of the volume of the bowl assembly.

   Syringe - A small rubber bulb syringe having a capacity at least that of the measuring cup.

Other accessory items including a metal or glass container, 1 quart capacity; a blunt-nosed brick mason's trowel; and a small scoop.

Calibration of Apparatus.
The volume of the bowl of the air meter in cubic feet; the accuracy of the graduations on the neck of the top section of the air meter and the volume of the measuring cup shall be checked for accuracy by the procedures set forth in Section 3 (a), (b), and (c) ASTM C-173.

Sample.
A representative sample of concrete shall be obtained by the procedures outlined in Test No. C-1.

Procedure.
1. Rodding and Tapping - Using the scoop, and aided by the trowel, fill the bowl with the concrete sample in three layers of equal depth. Rod each layer 25 times with the tamping rod, and tap the sides of the bowl 10 to 15 times or until no large bubbles of air appear on the surface of the rodded layer. In rodding the first layer the rod shall not strike forcibly the bottom of the measure. Only enough force shall be used in rodding the second and final layers to cause the rod to penetrate the surface of the previous layer.

2. Striking Off - After placing the third layer of concrete strike off the excess concrete with the strike-off bar until the surface is flush with the top of the bowl and wipe the flange of the bowl clean.

3. Adding Water - Clamp the top section into position on the bowl, insert the funnel, and add water until it appears in the neck. Remove the funnel and adjust the water level using the syringe until the bottom of the meniscus is level with the zero mark. Attach and tighten the screw cap.

4. Agitating and Rolling - Invert the assembly and agitate until the concrete settles free from the base; and with the neck elevated, roll and rock the unit until the air appears to have been removed from the concrete. Set the apparatus upright, jar it lightly, and allow to stand until the air rises to the top. Repeat the operation until no further drop in the water column is observed.

5. Dispelling Bubbles - When all the air has collected at the top of the apparatus, remove the screw cap, add one measuring cup full of isopropyl alcohol, in small increments. Use the syringe to dispel the foam on the surface of the water.

6. Reading - Read to the bottom of the meniscus formed by the liquid, estimating to the nearest 0.1 percent.

Calculations.

Calculate the air content of the concrete in percent by adding to the reading obtained, under procedure (6), the amount of alcohol used in procedure (5).

Test No. C-7

Air Content of Freshly Mixed Concrete - by the Air Indicator

General.

This method of test covers a procedure for determining the air content of freshly mixed concrete.

The equipment and procedures outlined may be used for a quick test to determine that the air content meets the contract requirements. Test results determined by this method, which indicate that the air content of the concrete does not meet the requirements, should be confirmed by additional tests using the equipment and procedures outlined in Test No. C-5, Pressure Method, or Test No. C-6, Volumetric Method.

Apparatus.

1. An air meter consisting of a metal measuring cup and a glass tube of proper size to receive the measuring cup at the large end, and at the smaller end, a reduced cylindrical shaped stem or neck of proper length, and graduated with uniform spacing marks. (See Figure 4-30D).

2. A plastic squeeze bottle containing a supply of isopropyl alcohol.

3. Narrow metal bladed knife or spatula.

Procedure for Determining Air Content.

1. Fill cup with cement mortar paste, excluding particles larger than #10 size. Use a narrow blade to pick up mortar. Rod material in cup to compact the mortar. Strike off excess mortar level with top of cup.

2. Insert cup assembly in glass tube. Using plastic bottle, introduce alcohol into tube through graduated stem until liquid is at the top graduation.

3. Place finger over stem opening to prevent loss of liquid and roll glass indicator from side to side gently to dissolve all mortar from cup into alcohol.

4. Place indicator in an upright position on a level surface and count the number of spaces the liquid has dropped in the stem. If the sample represents a mix containing 15 cu. ft. of mortar (water, air, cement and fine aggregate) the reading represents the percent of air in one cubic yard of concrete. For other proportions of mortar a correction is made using the conversion table furnished with the meter.

5. It is important that the reading be made immediately; holding the meter or permitting it to stand in the hot sun may cause the alcohol to expand and an erroneous reading may result.

6. After test is complete, clean all parts promptly with water and brush and dry thoroughly.

Recording Data.

The percent air content, method of determination, location concrete was placed in the structure, and the batch number sampled should be recorded in the Job Diary.

Test No. C-8

Weight Per Cubic Foot, Yield, and Air Content (Gravimetric) of Concrete

General.

This method of test covers the procedure for determining the weight per cubic foot of freshly mixed concrete and includes formulas for calculating:

1. The volume of concrete produced from a mixture of known quantities of the component materials.

2. The yield, that is, the volume of concrete per unit volume of cement.

3. The actual cement factor, and

4. The air content of the concrete.

The procedures outlined herein are covered in Fed. Test Method 233.0, ASTM Designation C-138 and AASHO Designation T-121. The air content determined by this test is primarily a laboratory procedure. It may have application if the correct values of the absolute volume of the component ingredients are known.

Apparatus.

1. Balance, a scale sensitive to 0.1 lb.

2. Tamping rod, a round, straight, steel rod 5/8" diameter and approximately 24 inches long having one end rounded to a hemispherical tip.

3. Measure, a cylindrical metal water tight measure, rigidly reinforced. The container should have a minimum capacity of 0.5 cubic feet, (approximately 10" diameter by 11" height).

4. Sampling bucket, shovels, mixing pan, glass cover plate and other minor laboratory equipment.

Calibration of Measure.

The measure is calibrated by accurately determining the weight of water at 62° F. (16.7° C.) required to completely fill the measure.

A glass cover plate may be used to aid in accurately filling the measure. Weigh the container with cover plate in place, making sure no air bubbles exist between water surface and glass cover.

The calibration factor for the measure is determined by dividing the unit weight of water at 62° F., namely, 62.4 pounds, by the weight, (in pounds) of water required to fill the measure.

Sample.

The sample of freshly mixed concrete is obtained at the time of delivery to the site, as outlined in ASTM Designation C-172, (refer to Test C-1).

Procedure.

Sequence of operations.--The measure is filled to one third of its capacity and the mass is rodded, as prescribed under rodding, evenly distributed over the cross section. The measure is then tapped and filled to two thirds capacity, the mass of concrete again rodded and tapped as previously indicated.

Rodding.--In rodding the first layer, the rod should not strike forcibly the bottom of the measure. In rodding the second and final layers, only enough force is used to cause the rod to penetrate the surface of the previous layer. For the 0.5 cu. ft. measure each layer is rodded with 25 strokes.

Tapping.--The exterior surface of the measure is tapped smartly with a piece of wood or rubber hammer 10 to 15 times, or until no large bubbles of air appear on the surface of the rodded layer.

Strike-off, cleaning, and weighing.--After consolidation of the concrete, the top surface is struck off and finished smoothly with a flat cover plate using care to leave the measure just level full. All excess concrete should be cleaned from the exterior and the filled measure weighed to the nearest 0.1 pound.

Calculations.

1. Weight per cubic foot - Calculate the net weight of the concrete by subtracting the weight of the measure from the gross weight. Calculate the weight per cubic foot by multiplying the net weight by the calibration factor for the measure used.

2. Volume of Concrete - Calculate the volume of concrete produced per batch as follows:

$$S = \frac{(N \times 94) + W_f + W_c + W_w}{W}$$

where:

S = Volume of concrete produced per batch in cu. ft.
N = Number of bags of cement in the batch.
94 = Net weight of a bag of cement, in pounds.
W_f = Total weight of fine aggregate in batch in the condition used, in pounds.
W_c = Total weight of coarse aggregate in batch in condition used, in pounds.
W_w = Total weight of mixing water added to batch, in pounds, and
W = Weight of concrete, in pounds per cubic foot.

3. Yield - Calculate the yield as follows:

$$Y = \frac{S}{N}$$

Where:

Y = Yield of concrete produced per 94 pound bag of cement, in cubic feet.
S = Volume of concrete produced per batch, in cubic feet, and
N = Number of bags of cement in the batch.

4. Cement Factor - Calculate the "actual" cement factor as follows:

$$N_1 = \frac{27}{Y} \quad \text{or} \quad N_1 = \frac{27\ N}{S}$$

Where:

N_1 = Number of bags of cement per cubic yard of concrete produced (actual cement factor).
Y = Yield of concrete produced per 94 pound bag of cement, in cubic feet.
N = Number of bags of cement in the batch, and
S = Volume of concrete produced per batch, in cubic feet.

5. Air content - Calculate the air content as follows:

$$A = \frac{T - W}{T} \times 100$$

or

$$A = \frac{S - V}{S} \times 100$$

Where:

A = Air content (percentage of voids) in the concrete.
T = Theoretical weight of the concrete, in pounds per cubic foot, computed on an air-free basis (see note).
W = Weight of concrete, in pounds per cubic foot.
S = Volume of concrete produced per batch, in cubic feet, and
V = Total absolute volume of the component ingredients in the batch, in cubic feet.

Note: The theoretical weight per cubic foot is, customarily, a laboratory determination, the value for which is assumed to remain constant for all batches made, using identical component ingredients and proportions. It is calculated from the formula:

$$T = \frac{W_1}{V}$$

Where:

- T = Theoretical weight of the concrete, in pounds per cubic foot, computed on an air free basis.
- W_1 = Total weight of the component ingredients in the batch, in pounds, and
- V = Total absolute volume of the component ingredients in the batch, in cubic feet.

The absolute volume of each ingredient is equal to the quotient of the weight of that ingredient divided by the product of its specific gravity times 62.4. For the aggregate components, the bulk specific gravity and weight should be based on the saturated surface-dry condition. For the cement a value of 3.15 may be used, unless, the actual specific gravity is determined by the standard method of test for Specific Gravity of Hydraulic Cement, ASTM Designation C-188.

Test No. C-9

Standard Methods of Sampling Stone, Slag, Gravel, Sand and Stone Block

General.

These methods of sampling are intended to be used for stone, slag, gravel, sand and stone block for the acceptance or rejection of the source of supply or the inspection of shipments of materials or materials on the site of work.

A complete procedure for sampling is outlined in ASTM Designation D-75, AASHO Designation T-2, and Fed. Spec. Test Method No. 101.01, "Standard Methods of Sampling Stone, Slag, Gravel, Sand and Stone Block for Use as Highway Materials."

Sampling Methods - Unprocessed Materials.

Stone from ledges or quarries.--Carefully inspect the face of the quarry to determine any variation in quality of strata or portions of the proposed quarry face to be used. Note any differences in structure, seams or color. Obtain separate unweathered samples from all strata that vary in color and/or structure. Mark bedding planes on the samples.

Sand and gravel.--Samples should be taken for the different bank materials that appear suitable for use. Open faced pits should be sampled by channeling the face at frequent locations removing uniform amounts throughout the length of channel. Overburden or loose materials at bottom of face should not be included in the sample. Deposits that are not opened may be sampled by means of pits or test holes. Pits excavated by dozer or back hoe equipment are preferred. The location and number of pits will be governed by the variations in materials encountered and the amount of material required for construction.

Representative samples should be taken by channeling the face of the pits, if the materials are to be excavated in a manner that will mix the total depth sampled. Pits that will be worked by dozers or other equipment on more or less level planes should be inspected very carefully for variable strata. Samples taken from various strata may be required to determine if the grading limits or quality of aggregate can be met.

Sampling Methods - Processed Aggregates.

Sampling at the plant.--Materials moved from stock piles or bins to freight cars or boats for transportation are normally sampled after loading. Three or more trenches should be dug across the car or compartment with the bottom of the trench at least one foot deep, one foot wide, and approximately level. Samples are taken along

the bottom length of the trench. Equal amounts of sample are removed by pushing a shovel downward into the material and not by scraping horizontally. About nine sampling points should be well distributed along the length of the trench including one at each edge of the car.

Samples may be taken from chutes or bins. The bin should be allowed to discharge 2-5 tons of material prior to taking the sample. Materials obtained for a sample are taken from the entire cross section of the flow of material as it is being discharged. A minimum of three specimens are required to form a composite sample.

Belt Conveyors.--May be sampled by stopping the belt and completely removing all of the material from a one to two foot cross section. Samples should be taken at more than one location, and extra precaution taken to remove all of the fines from the belt for the length and width of area sampled.

Stockpiles.--It is difficult to secure representative samples from a stockpile. During the placing of material it is normal to find that the coarser materials are segregated to the outer surface of the pile, especially in the vicinity of the base.

Stockpiles may be sampled by taking materials at or near the top of the pile, at or near the base and at an intermediate point. A board shoved into the pile just above the point of sampling will aid in preventing further segregation during sampling.

In sampling sand the outer layer should be removed until damp sand is exposed.

Fine aggregates may be sampled with a sampling tube, approximately 1-1/4 inches in diameter by 6 feet in length. Sufficient insertions should be made in various parts of the pile to obtain a representative sample.

Preparation and Size of Sample.

Extreme care is required in selecting and preparing samples for test, to insure that they are representative of the materials to be used on the project.

It is necessary to obtain an excess of material and then reduce it to a representative specimen of the desired size. The use of patented splitters is permitted, provided the sample is fed uniformly and simultaneously over the entire length of the splitter allowing equal volumes of materials to flow freely through each chute.

The quartering method is commonly used and is performed as follows:

1. Pile sample on canvas by placing each shovel full in center of cone so material runs down equally in all directions to mix the sample, Figure 4-31A.

2. Flatten the cone to spread material to a circular layer of uniform thickness, Figure 4-31B.

3. Using shovel or large trowel separate into four equal quarters and discard two opposite quarters, Figure 4-31C and D.

4. Remix the two quarters selected for the sample, and repeat operations 2 and 3. Continue this procedure until desired size of sample is obtained.

Sand sample should consist of not less than 10 pounds, coarse aggregates consisting of 1-1/2 inch minus not less than 70 pounds.

Bank run materials require samples of not less than 100 pounds.

All samples should be transported in close woven bags or tight containers to eliminate loss of fines.

Identification.

Each sample or separate container should be plainly identified by card or regular form setting forth:

1. Name of sample.

2. Source of supply - name, location.

3. Proposed use for the materials - project name and location.

4. Tests required.

A. *Composite sample placed cone formation.*

B. *Cone depressed to uniform frustrum section.*

C. *Sample divided into four equal segments.*

D. *Removing opposite segments. - To be used for test or further reduced by quartering method.*

Figure 4-31

Test No. C-10

Standard Requirements for Concrete Aggregates

General.
These standards are limited to screen analysis and fineness modulus tests which may be performed in the field laboratory and cover fine and coarse aggregates, other than light weight aggregates, for use in concrete.

Other test requirements are outlined in the contract reference specifications for concrete aggregates.

When visual inspection or laboratory tests indicate the need, samples should be taken from the aggregate source and submitted for additional tests prior to making formal acceptance of the aggregates for use in the work. Laboratory tests which may be required and are outside the limits of this write up include:

1. Amount of material finer than No. 200 sieve.

2. Organic impurities - sands.

3. Compressive strength - molded cylinders.

4. Soundness - sodium or magnesium sulphate method.

5. Clay lumps.

6. Coal and lignite - sand.

7. Abrasion of Coarse Aggregate.

8. Test for Soundness by Freezing and Thawing.

9. Test for Potential Alkali Reactivity of Cement Aggregate Combinations.

Detail procedures for making these tests are quite uniform and standard. They are included in Federal Test Methods, ASTM, AASHO and other reference sources.

Fine Aggregate.
Grading.--

1. Fine aggregates, unless otherwise specified, should be graded within the following limits:

Sieve	Percentage Passing
3/8 inch	100
No. 4	95 - 100
No. 8	80 - 100
No. 16	50 - 85
No. 30	25 - 60
No. 50	10 - 30
No. 100	2 - 10

2. The minimum percentages shown above for material passing the No. 50 and No. 100 sieves may be reduced to 5 percent and 0 percent passing if more than 3 percent air entrainment and more than 4-1/2 bags of cement per cubic yard are used or more than 5-1/2 bags of cement per cubic yard for concrete not having air entrainment. Certain mineral admixtures may also be used to make up deficiencies in these sieve sizes.

3. The fine aggregate should not have more than 45 percent retained between any two consecutive sieve sizes.

   The limits for the fineness modulus are limited to not less than 2.3 nor more than 3.1.

   The fine aggregate may be rejected if the fineness modulus varies by more than 0.20 from the values used in the approved mix unless adjustments are made in the proportions for the difference in grading.

Deleterious Substances.
The amount of deleterious substances in fine aggregates for concrete should not exceed the following: (based on percent by weight).

Item	Percent of Total Sample
Clay lumps	1.0
Material finer than 200 sieve:	
(a) concrete subject to abrasion	3.0
(b) Other Concrete	5.0
Saturated surface-dry material, coarser than No. 50 sieve, floating on liquid having specific gravity of 2.0	0.5

It is desirable to have the tests for deleterious substances in fine aggregates performed by an acceptable laboratory. Under certain conditions failure to meet the above tests may be omitted. However, the recommendation of the laboratory should be considered before giving approval for the aggregate source.

Coarse Aggregates.

Grading.--Coarse aggregates should be graded between the following limits:

Nominal Size	Amounts finer than each sieve (square opening - percent by weight)								
Nominal Size Square Opening	2"	1 1/2"	1"	3/4"	1/2"	3/8"	No. 4	No. 8	No. 16
1 1/2 to 3/4"	100	90-100	20-55	0-15	-	0-5	-	-	-
1 1/2 to #4	100	95-100	-	35-70	-	10-30	0-5	-	-
1" to #4		100	95-100	-	25-60	-	0-10	0-5	-
3/4" to #4			100	90-100	-	20-55	0-10	0-5	-
1/2" to #4				100	90-100	40-70	0-15	0-5	-
3/8 to #4					100	85-100	10-30	0-10	0-5

Deleterious Substances.
Coarse aggregates are approved on the basis of not exceeding the following limits: (based on percent by weight)

Item	Percent of Total Sample
Clay lumps	0.25
Soft particles	5.0
Material finer than 200 sieve	1.0
Saturated surface-dry material floating on liquid having specific gravity of 2.0	1.0

It is desirable to have tests for deleterious substances and other tests as required to determine quality of coarse aggregates, performed by an acceptable testing laboratory.

No aggregate source should be approved without satisfactory evidence that the materials will meet the requirements of the specifications.

Procedure for Sieve Analysis Fine and Coarse Aggregates.
The method of test for determination of the particle size distribution by screening or sieving is outlined in Standard Specification ASTM Designation C-136, Fed. Method 202.01 or AASHO Designation T-27.

Equipment.

Scales - accurate to 0.1 percent weight of sample.

Sieves - mounted to nesting frames with bottom and top covers.

Oven - uniform temperature (110± 5° C).

Samples.
Samples should be representative, using procedures for reducing size of sample by the quartering method or splitter apparatus.

The minimum amount of sample required for testing is as follows:

Nominal Size	Minimum weight sample, lbs.
4.76 MM (No. 4 screen -90% passing)	1.15
3/8 inch	2.25
1/2 inch	5.5
3/4 inch	11.0
1 inch	22.0
1-1/2 inch	33.0
2 inch	44.0

The selection of an exact weight of sample is not necessary.

Mixtures of coarse and fine aggregates are separated into two sizes, retained on and passing the No. 4 screen, prior to running the separate screen analysis.

Procedure.

1. Dry the sample to constant weight at a temperature of $110 \pm 5°$ C.

2. Separate the sample into sizes, using sieves which meet the requirements of the specifications.

   Sieves should be moved in a lateral and vertical motion accompanied by a jarring action to keep the sample moving over the surface of the sieve. The operation should continue until not more than 1 percent by weight of the residue passes any sieve during the lapse of one minute. The use of standard 8" diameter sieves and mechanical shaker, operated for a period of 10 minutes is recommended.

3. Weighing of the screened sample is cumulative starting with the material retained on the largest size sieve, and continuing in order of decreasing size until the material in the pan has been weighed. Extra caution is required that no material is lost in transferring from screen to scales. Each screen should be carefully cleaned, using a fine bristle brush.

Calculations.
Percentages are calculated on the basis of the total weight of sample including material finer than the No. 200 sieve, and include:

1. Total percentage of material passing each sieve.

2. Total percentage of material retained on each sieve, or

3. Percentage of material retained between consecutive sieves when specifications so indicate.

4. Report percentages to nearest whole number except results for material passing the No. 200 sieve which is determined to the nearest 0.1 percent.

Results of the sieve tests may be made on the Form SCS-535 "Sieve Analysis - Concrete Aggregates," and also may be shown graphically on Form SCS-353A.

Determination of Fineness Modulus.

The determination of fineness modulus of sand is made by adding the cumulative percentages retained on the following standard size sieves, Nos. 4, 8, 16, 30, 50 and 100, dividing the total by 100. Figure 4-32, a sample of Form SCS-535A, illustrates the results of test of a sand specimen and the computation of the fineness modulus for the sample. The results of the test of the fine aggregate is shown graphically in Figure 4-33.

The use of these forms is suggested for recording field test results.

FORM SCS-535A
(REV. 11-19-64)

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SIEVE ANALYSIS—CONCRETE AGGREGATES

Location ____________ Owner ____________

Watershed ____________ Sub-watershed ____________ Site No. ______

Contract No. ____________ Contractor ____________

Sampled by ____________ Tested by ____________ Date ______ 19 ______

Source of Aggregate ____________ Sample No. ______

Wt. of Pan and Sample 10.3# Wt. of Container and Sampler ____________

Wt. of Pan 2.1# Container Multiplier ____________

Wt. of Sample 8.2# Wt. per c.f. ____________ c.y. ____________

Sieve Size	Weight Retained	% Retained	Cumulative % Retained	Cumulative % Passing	Specification Limits
0.187 No. 4	.082	1	1	99	
.0937 No. 8	1.47	18	19	80	
.0469 No. 16	1.64	20	39	61	
.0232 No. 30	1.56	19	58	42	
.0117 No. 50	1.47	18	76	24	
.0059 No. 100	1.37	16	92	8	
Pan	0.66	8	-		
Fineness Modulus		100	285 / 100	= 2.85	

Sieve Size	Weight Retained	% Retained	Cumulative % Retained	Cumulative % Passing	Specification Limits
2"					
1½"					
1"					
¾"					
½"					
⅜"					
No. 4					

Remarks: ____________

Distribute as directed by State Conservationist

Figure 4-32

Form SCS 353
9-64

4-143

LABORATORY NO. ____

MATERIALS TESTING REPORT	U. S. DEPARTMENT of AGRICULTURE SOIL CONSERVATION SERVICE	SOIL CLASSIFICATION

PROJECT and STATE	SAMPLE LOCATION

FIELD SAMPLE NO.	DEPTH	GEOLOGIC ORIGIN

TYPE OF SAMPLE	TESTED AT	APPROVED BY	DATE

SYMBOL	DESCRIPTION

GRAIN SIZE DISTRIBUTION

C_c | C_u | $D_{MAX.}$ | D_{85} | D_{60} | D_{50} | D_{30} | D_{15} | D_{10}

COBBLES | GRAVELS | SANDS | FINES

SIEVE OPENING, (mm): (304.4) (152.2) (76.1) (50.8) (38.1) (25.4) (19.0) (12.7) (9.51) (4.76) (2.38) (2.00) (1.19) (0.841) (0.595) (0.420) (0.297) (0.250) (0.149) (0.105) (0.074)

US STANDARD SIEVE SIZE: 12" 6" 3" 2" 1½" 1" ¾" ½" ⅜" #4 #8 #10 #16 #20 #30 #40 #50 #60 #100 #140 #200

PERCENT FINER BY DRY WEIGHT: 100 90 80 70 60 50 40 30 20 10 0

GRAIN SIZE IN MILLIMETERS: 400.0 300.0 200.0 100.0 50.0 40.0 30.0 20.0 10.0 5.0 4.0 3.0 2.0 1.0 0.5 0.4 0.3 0.2 0.10 0.05 0.04 0.03 0.02 0.01 0.005 0.004 0.003 0.002 0.001

UNDISTURBED CONDITION

MOISTURE	DRY UNIT WEIGHT
%	g/cc pcf

SHRINKAGE LIMIT %

SOLUBLE SALTS %

ATTERBERG LIMITS

NATURAL MOISTURE		AIR DRY		OVEN DRY	
LL	PI	LL	PI	LL	PI

SPECIFIC GRAVITY (G_s)

(-) #4	(+) #4

REMARKS:

Test No. C-11

Specific Gravity and Absorption of Fine Aggregates

General.

This method of test is intended for use in making determinations of bulk specific gravity (saturated surface dry basis) and absorption of fine aggregates.

Test procedures should be in accordance with the standard method outlined in ASTM Designation C-128, AASHO Designation T-84 or Fed. Method 209.1, "Specific Gravity and Absorption of Fine Aggregate."

Apparatus.

1. Balance - A balance having a capacity of 1000 grams and sensitive to 0.1 gram.

2. Flask - A volumetric flask of 500 ml capacity, calibrated to 0.15 ml at 20° C.

3. Conical Mold - A conical metal mold 1-1/2 inch and 3-1/2 inch diameter top and bottom respectively and 2-7/8 inch in height.

4. Tamping rod - A metal tamping rod weighing 12 oz. and having a flat circular face 1 inch in diameter.

Sample.

Obtain approximately 1000 grams of representative sample using procedure outlined in Test No. C-9.

Procedure.

1. Cover sample with water for period of twenty-four hours.

2. Spread sample on a flat surface exposed to a gentle current of warm air. Stir frequently to secure uniform drying, until sample approaches free flowing condition.

3. Place loose sample in mold and lightly tamp 25 times, with tamping rod, lift mold vertical from table. If molded sample retains shape, free moisture is retained by sample.

4. Continue drying, with constant stirring and test at frequent intervals until cone slumps upon removal of mold, indicating surface dry condition of sample.

5. Immediately introduce into the flask 500 gr. of the air dry material and fill flask to 500 ml mark with water at 20° C.

6. Roll flask on flat surface to eliminate air content.

7. Place in constant temperature water bath maintained at 20° C. for one hour.

8. Fill with water to the 500 ml mark and determine to nearest 0.1 gr. the <u>total</u> weight of water placed in the flask.

9. Remove fine aggregate from flask and dry to constant weight at $110 \pm 5°$ C.

10. Cool to room temperature and weigh.

Computations.
Bulk Specific Gravity (saturated surface dry basis) equals

$$\frac{500}{V-W}.$$

Absorption.
Percentage of Absorption $= \frac{500 - A}{A} \times 100.$

Where: A = weight in grams of oven-dry sample in air.

V = volume in milliliters of flask.

W = weight in grams or volume in milliliters of water added to flask.

Recording Test Data.
Results of the specific gravity and absorption tests may be recorded under the appropriate columns on Form SCS-544 "Daily Concrete Batching Record" (Concrete Batch and Yield Computations) Figure 5-2.

Test No. C-12

Specific Gravity and Absorption of Coarse Aggregate for Concrete

General.

This method of test is intended for use in making determinations of bulk specific gravity (saturated surface dry basis) and absorption of coarse aggregates used in the manufacture of concrete.

The procedure for making the Test is outlined in detail in the Standard Method ASTM Designation C-127, AASHO Designation T-85, or Fed. Specification Method 209.0.

The apparatus and procedure for performing the test is the same as outlined for determining the specific gravity and absorption of the rock fraction contained in embankment materials. Therefore, reference should be made to Test S-15 for detail requirements in making the test. A test sample of approximately 11 pounds is required.

Recording Test Data.

Computations for the specific gravity of the aggregate may be recorded on SCS-543"Bulk Specific Gravity Rock, Gravel, etc."Figure 4-26. Results as required may also be entered on Form SCS-544 "Daily Concrete Batching Record" Figure 5-2.

Test No. C-13

Surface Moisture in Fine Aggregate

General.

This method of test covers a procedure for rapid determination in the field of Surface Moisture in Fine Aggregate by displacement in water.

Test procedures are outlined in the Standard Method ASTM Designation C-70 and the B. of R. "Concrete Manual" (Des. 11) "Surface Moisture in Fine Aggregate."

Apparatus.

1. Balance - a balance having a capacity of 2000 grams.

2. Flask - a standardized volumetric flask of 500 milliliter capacity, calibrated to 0.15 milliliters.

Note: A Chapman flask may be used in lieu of the volumetric flask. This flask may also be used for specific gravity and absorption determinations.

3. Pipette - a 1/4 inch diameter glass tube of sufficient length to adjust the water level in the flask.

Sample.

A representative sample of the fine aggregate, weighing not less than 1000 grams. The sample should be carefully selected to be representative of the average moisture condition, and kept in a covered container from the time of taking the sample until tested.

Procedure.

1. Fill flask with water at room temperature to just above the calibrated 200 milliliter mark.

2. Lower level by means of pipette until lowest point of water surface coincides with the 200 milliliter mark.

3. Accurately weigh 500 grams of fine aggregate sample and introduce into the flask containing predetermined volume of water.

4. Read directly on the graduated scale of the flask, at the bottom of the water surface, the combined volume of the fine aggregate and water.

Calculations.

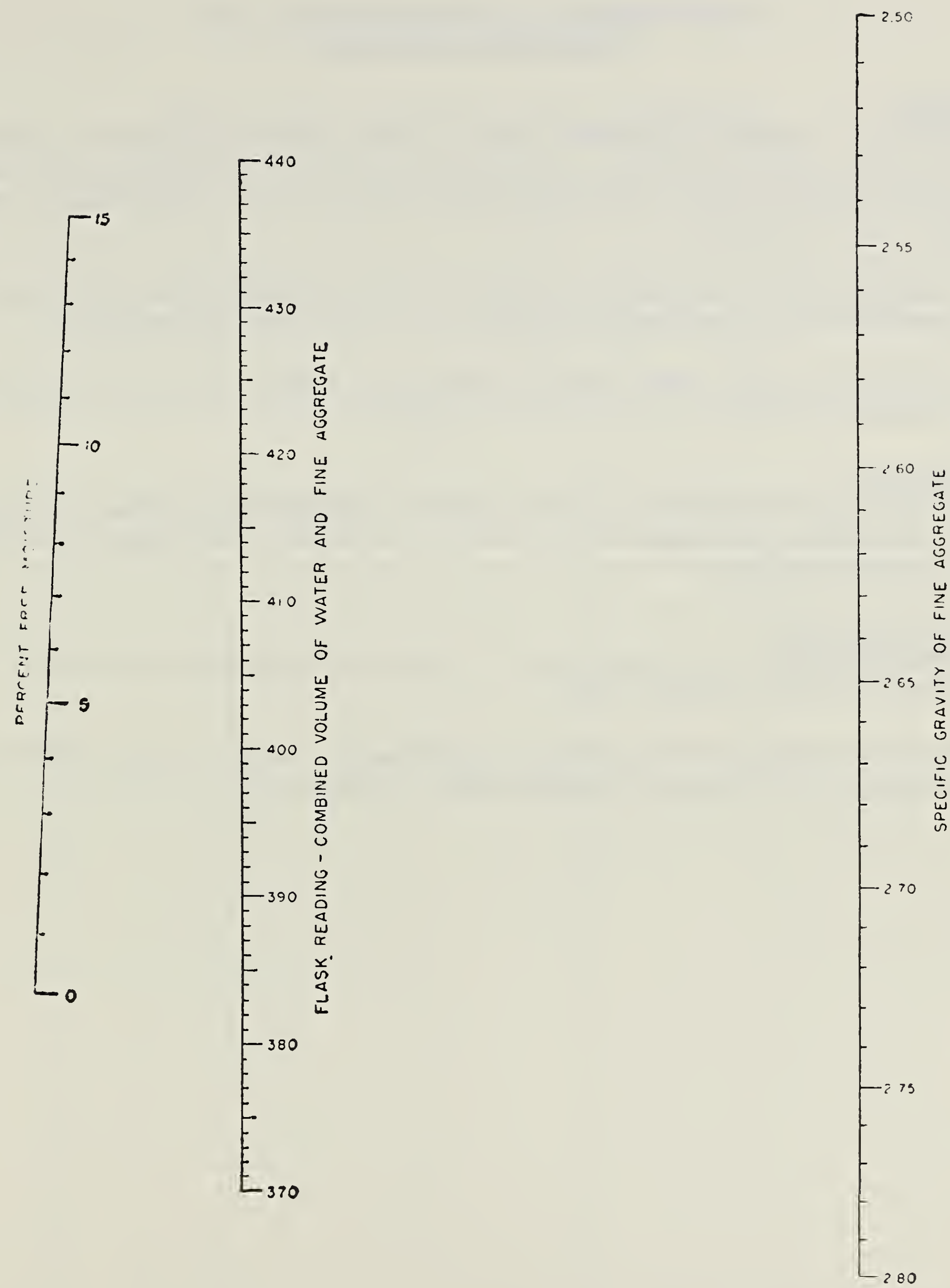
$$\text{Percent moisture in fine aggregate} = \frac{\left(V - \frac{500}{s.g.}\right) - 200}{(200+500) - V}$$

Where V = flask reading; combined volume of the fine aggregate and water in the flask.

s.g. = bulk specific gravity of the saturated surface dry fine aggregate.

The amount of surface moisture may be read directly from the straight line nomograph, Figure 4-34, for the corresponding flask reading and bulk specific gravity.

Recording Data.
Results of the surface moisture in fine aggregates may be recorded under the appropriate headings on Form SCS-544 "Daily Concrete Batching Record," (Concrete Batch and Yield Computations) Figure 5-2.



Nomograph for determining free moisture in fine aggregate with a calibrated flask.

Bureau of Reclamation Concrete Manual

Figure 4-34

Test No. C-14

Determination of Screen Analysis for Drain Fill Aggregates

General.

The size of sample, equipment and test procedure outlined for concrete aggregates, Test No. C-10, may also be used for determining the particle size distribution for drain materials used for construction items, other than concrete.

The sample should be representative using procedures for reducing size of sample by the quartering method or by splitter equipment.

The proper screen sizes, and the allowable range for each size should be determined from the contract documents.

Procedure.

The detail procedures set forth in Test C-10 should be used to make the specified size separations, and to determine the required weight and percentage data.

Recording Data.

Results of the sieve separation, by the specified sizes may be recorded on Form SCS-535B, Figure 4-35.

The results may also be compared graphically, with the specified limits by plotting the data on Form SCS-353A, Figure 4-33.

FORM SCS-535B
(REV. 11-19-64)

U. S. DEPARTMENT OF AGRICULTURE
Soil Conservation Service

SIEVE ANALYSIS - DRAIN FILL OR FILTER AGGREGATES

Location ______________________ Owner ______________________
Watershed ______________________ Sub-Watershed ____________ Site No. ________
Contract No. ______________________ Contractor ______________________
Sampled By ______________________ Tested By ____________ Date ________
Source of Aggregate ______________________ Sample No. ________
Wt. of Pan and Sample ______________________ Dry Weight Sample, in grams ________
Wt. of Pan ______________________ Dry Wt. Washed Sample, grams ________
Wt. of Sample ______________________ % Material finer than #200 Sieve ________

Sieve Size	Weight Retained	Weight Passing	Percent Passing	Percent Retained	Specification Limits

Remarks: ______________________

____

____

____

Figure 4-35

Test No. C-15

Materials Finer Than No. 200 Sieve in Mineral Aggregates By Washing

General.

This method covers a procedure for determining the amount of material finer than No. 200 sieve in aggregates that are removed by washing the clay and other particles that are dispersed by the wash water.

Detail test procedures are outlined in the Tentative Method ASTM Designation C-117, "Materials Finer Than No. 200 Sieve in Mineral Aggregates by Washing."

Apparatus.

Balance.-- A scale having capacity of 5000 grams and sensitive to 0.1 percent, weight of sample.

Sieves.-- A nest of two sieves, the lower a No.200 and the upper a No. 16.

Container.--A covered can with water tight lid.

Oven.--An oven of sufficient size, capable of uniform temperature 110° ± 5° C.

Sample.

A sample carefully selected to be representative of the aggregate and which contains sufficient moisture to prevent segregation and should conform to the following approximate weights:

Nominal Maximum Sieve Size	Approximate Minimum Weight-Grams
#4	500
3/8 inch	2000
3/4 inch	2500
1-1/2 inch or larger	5000

Procedure.

1. Dry sample to constant weight at 110° ± 5° C. and weigh to 0.1 percent weight of the sample.

2. Place dry sample in the container and cover with water: Agitate vigorously to separate particles finer than No. 200. Immediately pour wash water over nested sieves (coarser sieve on top). Avoid the decantation of the coarser particles of the sample.

3. Add second wash water to sample and repeat step (2). Continue washing procedures until wash water is clear.

4. Return all material retained on the sieves by flushing to the washed sample.

5. Dry the washed sample to constant weight at a temperature of 110° ± 5° C., and weigh to nearest 0.1 percent weight of sample.

Calculations.
Determine the amount of material passing a No. 200 sieve as follows:

$$A = \frac{B - C}{B} \times 100$$

Where: A = Percentage of material finer than No. 200 sieve.

B = Original dry weight of sample, in grams.

C = Dry weight of sample, after washing, in grams.

Recording Data.
Results of the test may be recorded on SCS-535B, Figure 4-35.

Graphical Method for Blending Aggregate Sizes

General.

The problem of blending three different size aggregates to meet a specified grading may occur under certain construction conditions.

The determination of the correct blend on a cut and try approach can be a challenge.

The graphical method developed by Mr. George F. Driscoll presents a simple solution that may be carried to completion in a relatively short time on the job. The detail procedure included herein is a reprint from the Engineering - News Record Magazine, copyright of 1961.

Procedure.

The sieve analysis for each proposed aggregate is required. If not available, samples may be taken and the materials tested as outlined in Test C-10. The specified gradation limits may be determined from the contract specifications.

The graphical determination, using triangular coordinate paper, is made as shown on Figure 4-36.

GRAPHICAL METHOD SIMPLIFIES ECONOMICAL BLENDING OF AGGREGATES

By George F. Driscoll

Economical blending of three differently sized aggregates to meet a specified gradation presents a challenge to engineers, contractors and aggregate producers. Proportioning methods are available, including one presented previously by the author (ENR June 19, 1952, p. 108).

The method described below offers advantages of simplicity and completeness. It is not necessary to make several trials; one solution shows all possible proportions. If the three available aggregates can not be proportioned to meet the specification, one solution clearly indicates that fact. The work can be done without a scale or any computations if a T-square and triangle are used. It is helpful to use several sheets of triangular coordinate paper, transferring the limit lines to an answer sheet as developed.

The method uses gradations of the separate aggregates expressed in terms of total percentages passing each size of sieve.

The use of triangular coordinate paper is based upon the fact that the sum of the distances from any point in an equilateral triangle to the three

Mr. Driscoll, veteran highway engineer, teacher and contractor, now is Associate Professor of Civil Engineering at the University of Dayton.

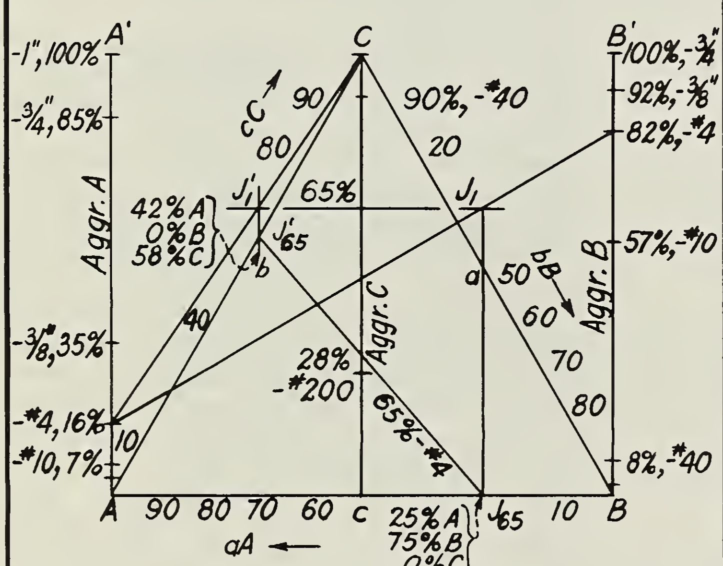


Fig. 1

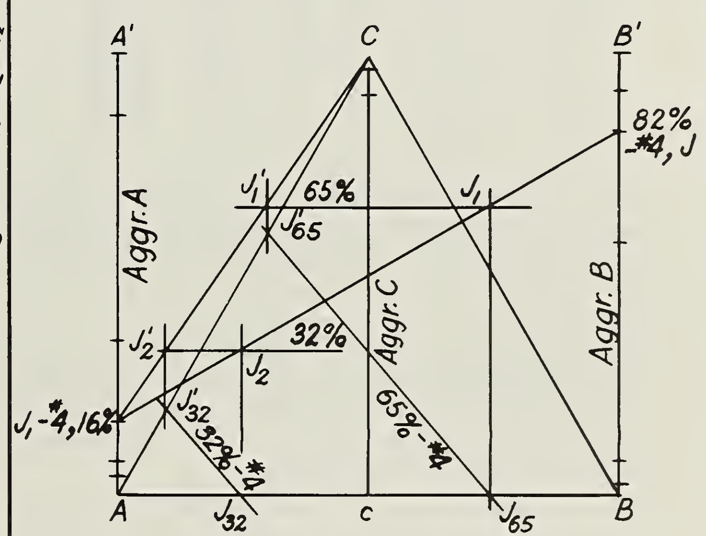


Fig. 2

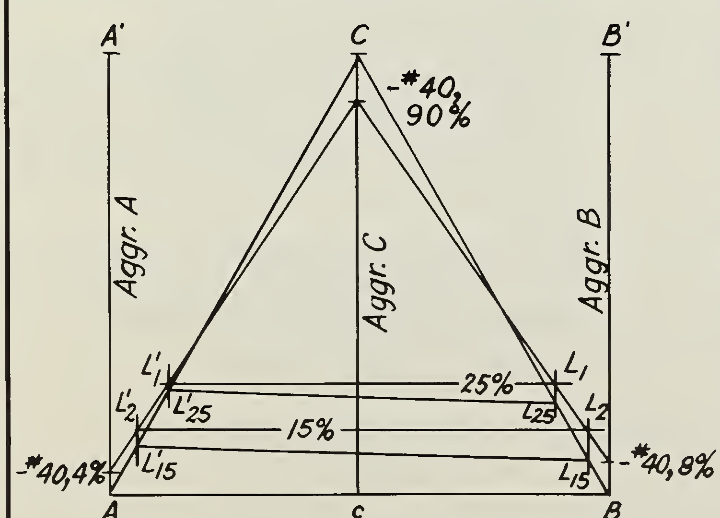


Fig. 3

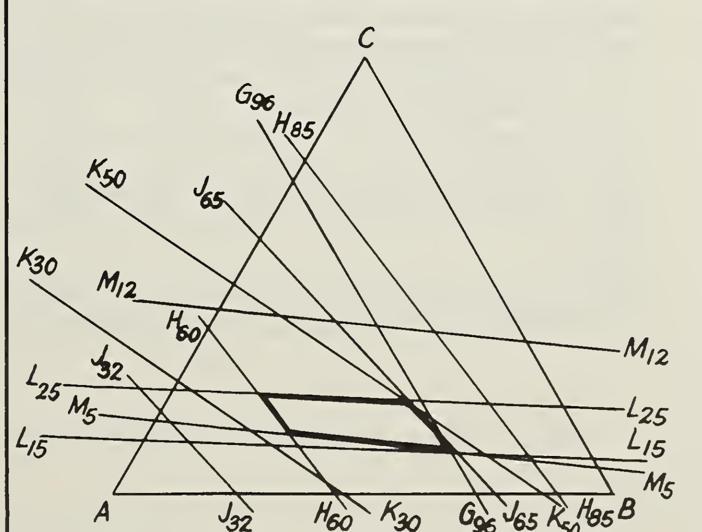


Fig. 4

sides is constant and equals the length of one side. In this case, the sum is 100%.

In a plot like figure 1, the point A represents 100% of Aggregate A, measured from point a; point B represents 100% of Aggregate B, measured from point b; and point C represents 100% of Aggregate C, measured from point c.

As an example of the use of the method, consider three aggregates, gradings for which are given in the table. The aggregates are to be combined in such proportions that the blend will meet the specification limits given in the last column.

Aggregate Gradings

Total Percentages Passing

Symbol	Sieve Size	Available Aggregates A	B	C	Specification Limits
F	1 in.	100	100	100	100
G	3/4 in.	85	100	100	75-96
H	3/8 in.	35	92	100	60-85
J	4	16	82	100	32-65
K	10	7	57	97	30-50
L	40	4	8	90	15-25
M	200	0	3	28	5-12

As a first step, erect a vertical line for each aggregate; A′A, B′B and Cc (see figure 1). Represent the grading of each aggregate by measuring the respective percentages from the base line (AcB) to the mark for each sieve size.

If Aggregates A and B are blended you can measure the percentage of A in the blend on line AcB; for a blend of A and C, measure the percentage of C on line AC; and for a blend of C and B, measure the percentage of B on line CB.

Consider that portion of the aggregates passing the No. 4 sieve, symbol J (specification limits, 32-65%). Draw a line from 16% on A′A to 82% on B′B. Blends of Aggregates A and B will yield from 16 to 82% of –No. 4 material, as the percentage of A in the blend varies from 100% to 0%.

Next, find the percentage of A required to yield 65% J by locating the intersection of the 16%-82% line with the 65% horizontal line at J_1. Project this intersection vertically to the AB line at J_{65}. Since the line AB is 100% long, the distance J_{65}-B is the percentage of A which, when proportioned with B, will yield a blend with 65% of –No. 4.

Draw the line 16% (A′A) to 100% (Cc) in figure 1 and find its intersection J'_1 with the horizontal 65% line. Project this intersection vertically to the line AC at J'_{65}.

The point J'_{65} represents the percentage of C necessary to make the –No. 4 portion of the blend of A and C equal to 65%.

Draw a line from J'_{65} to J_{65}. This line represents numberless blends of aggregates A, B and C, all yielding 65% of –No. 4 material. Note that point J_{65} represents 25% A, 75% B and 0% C; J_{65} represents 42% A, 0% B and 58% C.

To complete the work on the –No. 4 fraction, refer to figure 2. Intersect the 16%-100% line with the 32% horizontal line at J'_2. Project this intersection vertically to the AC line at J'_{32}, which indicates that an 81% A - 19% C blend will have 32% passing the No. 4 sieve.

Next, intersect the 16%-82% line with the 32% horizontal line at J_2.

Project this intersection vertically downward to the AB line at J_{32}, which indicates that a 76% A - 24% B (0% C) blend will have 65% passing the No. 4 sieve.

Draw a straight line from J'_{32} to J_{32}. Any proportion of A, B and C represented by points on the line J'_{32} - J_{32} will yield a blend with 32% passing the No. 4 sieve.

Consideration of the area enclosed by the line J'_{65} and J_{65} and the line J'_{32} and J_{32} reveals that the method is simple and complete. Any point in this area represents a blend of Aggregates A, B and C that will meet the specification for the No. 4 sieve.

Figure 3 shows how the limits of proportions to meet the specifications for the No. 40 sieve are determined using the same basic procedures.

Diagrams illustrating the work for fractions F, G, H, K and M are not shown, but all limit lines have been transferred to figure 4 to show the final results. It is unnecessary to draw any lines for the 1-in. size (F); only one line is shown for the 3/4-in. size (G). The other 3/4-in. line passes through point A, since 100% of Aggregate A would yield the smallest percentage passing a 3/4-in. sieve.

In figure 4, the area enclosed by heavy lines is within all limits and encloses points representing all possible proportions of Aggregates A, B and C that can be used to obtain a specification blend. Aggregate A can vary from 28.7 to 59.6%; B from 17 to 60%; and C from 11 to 23.5%.

If an area is not enclosed by each pair of limit lines, it is impossible to meet the size specifications with the available aggregates.

NATIONAL ENGINEERING HANDBOOK

SECTION 19

CONSTRUCTION

CHAPTER 5. RECORDS AND REPORTS

Technical Photographic Coverage for Contract Documentation

General.
Watershed Memorandum SCS-65 outlines the importance and the requirements for photographic documentation of Contract Construction Operations. It also states that properly documented photos may be admitted in court. Construction photos are equally applicable to informal contract work as to larger watershed construction. Each state should develop a plan for the extent of coverage and designate the party responsible for taking the photographs. Definite arrangements should be made in advance of construction operations for each project to obtain the necessary photos for contract administration and other purposes.

If pictures, whether black and white or color slides, are to be of value and effective they should be clear and properly documented. Each picture needs to be identified by number and cross referenced to a log which states the time, date, location of subject and camera, a descriptive caption and the name of the photographer.

A reference in the Job Diary is recommended, when pictures are taken of unusual conditions or unsatisfactory operations.

The taking of pictures of questionable or unacceptable work may create relationship problems with the contractor. Extra precaution should be taken to explain in a diplomatic manner the reason for photographic documentation.

Listed below are conditions which suggest the need for photographs:

1. When dewatering is inadequate.

2. When changed conditions are anticipated or apparent (a series of photos may be needed).

3. When borrow areas are improperly managed (drainage, prewetting, use of material).

4. When materials are damaged or rejected.

5. When concrete forms appear inadequate.

6. Improper placement, finishing or curing of concrete.

7. Honeycomb or damaged concrete work.

8. When failures occur (structural members, channel slopes, etc.)

9. Damage caused by floods or heavy rains.

10. When safety requirements are not complied with.

11. When property damage occurs outside the work limits.

12. When it is apparent that a specific job is improperly staffed, or unsatisfactory equipment or plant is provided for the work.

13. When changes or contract modifications are required, that can be documented by photographs.

14. Results of accidents or circumstances causing injury to workmen or others. (Equipment, scaffolding, roads, etc.)

Adequate photographs should also be taken of the operations, even though the work is satisfactory, to show that the various bid items have been constructed in accordance with the requirements of the contract, and to show stage of progress on a given date of various elements of the work.

Weekly Summary of Density Determinations - (SCS-532)

General.
Form SCS-532 (see Figure 5-1) may be used to record weekly summaries of field density determinations for earthwork on a particular construction site.

Preparation of Summary.
Heading.--Location - Location of the field office administering the contract.

Owner - The name of the Contracting Organization or landowner(s) involved.

Submitted By - Name of engineer or inspector.

Date - Date the report was submitted.

Watershed, Sub-watershed, Site No., Contractor, Contract No.- Show exactly as they are in the contract.

Report Period: From - To - Indicate the month, day and year in both instances.

Body of summary.--The data shown on the form is taken directly from the work sheets prepared in connection with field density determinations, Forms SCS-530A or 530B. Instructions to the contractor should be summarized in the report if any corrective action was found necessary as the result of a test.

Include data on retests made on sections of the embankments ordered to be reworked.

Distribution.--Original - Retained in office responsible for engineering services.

Copy - State Conservation Engineer

Copy - Government Representative (when engineering services other than SCS)

Copy - E&WP Unit (optional - mutual agreement by State and Unit)

Form SCS-532
(Rev. 11-19-64)

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

WEEKLY SUMMARY OF DENSITY DETERMINATIONS

Location Safford, Arizona Owner F.C.S.W. Sponsors Submitted By: D. Riddle Date 3/23 19 64

Watershed Frye Creek-Stockton Wash Sub-watershed Stockton Wash Site No.

Contractor Royden Construction Company Contract No. F.C.S.W. #5 Report period: From 3/16 19 64 to 3/20 19 64

Test No.	Date of Test	Location of Sample: From (Dam, Core, etc.)	Location of Sample: Sta. No.	Location of Sample: Distance Rt. or Lt. of ℄	Elev.	Particle Control Size	Corr. % Moist.	Dry Density Lbs/C.F.	Opt. Moist. %	Max. Dry Density Lbs/C.F.	% Comp.	% Comp. Spec.	Instructions to Contractor	Tested By
5-109	3/16	Dam	125+00	Rt. 10', ℄	2994.6	-#4	13.4	116.1	13.6	119.0	97.6	95	O.K.	E.T.
5-110	3/16	"	132+00	℄	2998.4	"	15.9	112.9	13.6	119.0	94.9	95	O.K.	E.T.
5-111	3/16	"	122+00	℄	2992.9	"	17.0	102.6	18.3	104.0	98.7	95	O.K.	E.T.
5-112	3/16	"	110+00	Rt. 30', ℄	2992.5	"	18.9	105.6	17.1	106.2	99.4	95	O.K.	E.T.
5-113	3/17	"	117+00	℄	2995.6	"	13.7	112.8	15.3	114.8	98.3	95	O.K.	E.T.
5-114	3/17	"	114+00	℄	2995.2	"	10.3	104.4	12.1	110.3	94.7	95	Additional rolling required.	E.T.
5-115	3/17	"	111+00	Lt. 20', ℄	2997.5	"	16.7	111.5	15.3	114.8	97.1	95	O.K.	E.T.
5-116	3/17	"	126+00	Rt. 10', ℄	2995.2	"	11.5	115.3	10.9	117.0	98.5	95	O.K.	E.T.
5-117	3/18	"	109+00	Rt. 20', ℄	2997.0	"	18.8	107.1	16.4	109.3	98.0	95	O.K.	E.T.
5-118	3/18	"	116+00	Rt. 40', ℄	2994.3	"	10.1	114.6	10.9	117.0	97.9	95	O.K.	E.T.
5-119	3/18	"	134+00	Rt. 59', ℄	2999.8	"	11.2	113.1	10.9	117.0	95.0	95	O.K.	E.T.
5-120	3/19	"	131+00	℄	3000.7	"	16.2	113.7	15.3	114.8	99.0	95	O.K.	E.T.
5-121	3/19	"	108+00	Lt. 50', ℄	2998.0	"	17.2	112.2	16.4	114.1	98.3	95	O.K.	E.T.
5-122	3/20	"	128+00	℄	2999.2	"	7.2	109.8	12.6	119.4	92.0	95	Add water mix and recompact	E.T.
5-123	3/20	"	133+00	Lt. 22', ℄	2999.7	"	12.2	111.2	13.1	114.0	97.5	95	O.K.	E.T.
5-124	3/20	"	128+00	℄	2999.2	"	10.1	113.8	12.5	119.2	95.4	95	O.K. after rework (see #122)	E.T.

Figure 5-1

Daily Concrete Batching Record (SCS-544)

General.
It is desirable to maintain inspection of the operations of the batch or mixing plant on all projects for which the mix is designed and controlled by the Contracting Organization. Likewise, it may be determined under certain situations, inspection will be required at the batching plant for the projects on which the Contractor has responsibility for the design of the mix. Such inspection would determine that the quality of the materials and the batch weights of the various ingredients are supplied in accordance with the specifications and the requirements for the approved mix. When field tests of aggregates and moisture determinations are made they should be performed and recorded as outlined in Chapter 4, Sampling and Testing.

Form SCS-544 (see Figure 5-2) has been prepared for use by the plant inspector to record the operations at the plant for each pouring operation.

Preparation of the Form.
Heading.--self explanatory, information available from construction office and batching plant records. Pour number should correlate with office records as predetermined for the job.

Body of report.--Batch Quantity and Volume - Record total number of batches. Record totals for equal volume and scale setting on one line for the days run. Use a new line for each change in scale setting which would also reflect a change in mix or volume of batch.

Mix Number - Record number of mix or actual ratio of ingredients used.

Weights - Cement and Aggregates - Show in the proper columns and lines the scale batch weights for each material or material size, including proper allowance for surface water in aggregates.

Mixing Water - Include gallons surface water in aggregates and the actual gallons of water contained in the mix.

Admixtures - Record total pounds or amount liquid measure added to each batch.

Quantities for 1.0 cu. yd.--Complete this portion of the form. This data is important for checking scale settings for variable size batches.

Total production.--Complete record to show computed total quantity concrete and cement, as determined from number of batches, volume and scale setting per batch.

Signature.--Plant inspector should sign each day's report.

Batch and Yield Computations (back of form).
This portion of the form may be used to record quantities of ingredients required for a batch and also for computation of actual yield of a batch - on a one sack or one cubic yard basis.

Distribution.
1 copy - Project office file, retain as supporting data to other concrete placing and quality records for the project.

SCS No. 544
(Rev. 11-19-64)

DAILY CONCRETE BATCHING RECORD

Watershed Pine Creek Watershed Project Dam #3 Date 3/16/64
Structure or Site No. Principal Spillway Plant Name American Conc. Co. Report No. 3
Contractor Woods Constr. Co. Plant Location Lakeside, U. S.A. Weather cloudy-cool
Type Mixing Equip. Transit truck Kind Admixture air entraining Class Conc. 3000#
Source: Cement Lehigh Sand Lakeside Pit #2 Coarse Aggregate Lakeside Pit #2
Time Operation: From 8:00 a.m. to 11:30 p.m. Pour No. or Location Floor slab - emergency spillway

Batch		Mix	Cement	Fine Aggr. Wt.			Coarse Aggr. Wt. #4-1 1/2"			Coarse Aggr. Wt.			Mixing Water-gal.			Admixture	
Quantity	Vol. c.y.	No.	Wt.	S.S.D.	%M	Batch	S.S.D.	%M	Batch	S.S.D.	%M	Batch	In Aggr.	Add.	Total	lbs.	Air Entrain.
12	6.0	A-4	3102	7050	3.0	7260	11,400	0.5	11,457	—	—	—	32	178	210	—	24 oz.
1	3.0	A-4	1551	3025	3.0	3630	5,700	0.5	5,730	—	—	—	16	89	105	—	12 oz.

Quantities for 1.0 Cu. Yd.

	Fine Aggr.	Coarse Aggreg.		
Aggregates-Wt. lbs. Sat. & Sur. Dry	1175	1900		
Moisture - %	3.0	0.5		
- lbs.	35.0	9.5		
Scale batch weight	1210.0	1910		

Cement: (5.5) sacks 517 pounds
Water: Surf. Aggr. 5.4 gals; Add. 29.6 gals; Total 35.0 gals.

Total Production:
No. of batches 12.5 Batch Vol. 6.0 C.Y.
Total Quantity 75.0 C.Y.
Total Cement sks. 41,775 lbs.
Remarks:

Inspector J. R. Smith

Figure 5-2

CONCRETE BATCH AND YIELD COMPUTATIONS

BATCH QUANTITIES - ONE ~~SACK~~ CU. YD. BATCH

Property	Cement	Water	Sand	Coarse Aggregate			Total
				-1½"			
Proportion by weight							
Batch weights, lbs. (Agg. sat. & surf. dry)	517	247	1175	1900			3839
Total moisture in agg., % by weight	— —	— —	—	—			
Absorption (sat. factor) of agg., % by weight	— —	— —	—	—			
Surface moisture in agg. % by weight (by test or assumed)	— —	— —	3.0	0.5			
Surface moisture in agg., lbs. (% x wt. of agg. ÷ 100)	— —	— —	35.0	9.5			45.0
Batch weights, lbs.	517	247	1210	1910			3884

NOTE:

If surface moisture of aggregate is determined directly by test or assumed, the lines for total moisture and absorption are omitted.

YIELD - ONE ~~SACK~~ CU. YD. BATCH

Property	Cement	Water	Sand	Coarse Aggregate			Total
Batch weights, lbs. (Agg. sat. & surf. dry)	517	292	1175	1900			
Specific gravity (assumed for cement, by test or assumed for aggregate)	3.12	1.00	2.65	2.65			
Absolute volume, cu. ft. $= \frac{\text{wt.}}{\text{sp. gr.} \times 62.4}$	2.65	4.77 Assume 5% air.	7.10	11.50			26.02 1.30 27.32

Yield = cu. ft. concrete per sack of cement - - - - - = 4.84 cu. ft.

Sacks cement per cu. yd. of concrete - - - - - - - = 5.54 sacks

$$\text{Yield} = \frac{\text{Tot. wt. materials}}{\text{Unit weight of concrete, lbs./cu. ft.}} = \frac{3884}{145} = 26.8 \text{ cu. ft.}$$

Figure 5-2 (Back)

Pile Driving Record (SCS-545)

General.

Form SCS-545, (Figure 5-3) has been prepared for use in maintaining a progressive record of installation of individual piles for a structure or a specific portion of a structure. Additional driving record forms may be used for structures that have multiple site requirements.

Preparation of the Form.

Heading.--Self explanatory. Special attention should be given to clearly identifying the structure or portion of the structure for which the record applies.

Bearing value formula, capacity and maximum "S".--These headings apply only when the formula method is specified for control.

Hammer data.--Fill in applicable headings depending on type of hammer used.

Body of form.--Use one line for complete driving record per pile. The various column headings are self explanatory. All the necessary data should be available from field note records.

Reverse Side of Form.

This space should be used to show location and approximate dimension of the pile driving site. Each individual pile location should be indicated in its relative position including the assigned number for each pile. Include bent number, stationing, orientation arrow and such other data as necessary to identify the site. Reference to detail layout in the contract drawings may be used in lieu of a sketch, when adequately shown on the drawings.

SCS No. 545
(Rev. 11-19-64)

Pile Driving Record

Watershed Doe Creek
Structure A-1

Contract No. 1-DC-64
Contractor D. H. Hammer & Sons

Name & Model Hammer Vulcan "V" (Gravity type)

Manufacturer's Rating - "E" — Ft. lbs/blow
Average blows/minute

Bearing value formula - "R" = $\frac{2\,W\,H}{S+1.0}$ lbs.
Minimum bearing capacity required 50,000 lbs.
Maximum allowable "S" 1/ 0.44 inches
1/ S = Average penetration/blow - last few blows.
Type & kind of piles Round creosoted fir timber

W - Wt. of hammer or ram 3000 lbs.
H - Length stroke or fall 12' ft.
A - Effective area piston — Sq. In.
P - Mean effective pressure — #/Sq. In.

Date	Pile No.	Penetration			Comp'd Bear'g "R" #'s	Elevation		Length cut-off	Length Pile in Leads	Length Pile in Place	Diameter of Pile		Remarks
		No. Blows & Drop	Total (In.)	"S" (In.)		Top Pile	After Cut-off				Butt (in.)	Tip (in.)	
5/20/64	1	5@ 12	1 3/4	0.35	53,250	145.9	145.1	0.8	18.2	17.4	10	8	
"	2	5@ 12	2.0	0.40	51,450	146.4	145.1	1.3	18.5	17.2	11	8½	

Figure 5-3

Engineering Notes - Pile Driving Record

General.
The engineering notes shown in Figure 5-4 illustrate a format that may be used to set up headings in the field notebook for recording driving data of individual piles of various kinds and types. The arrangements of the headings has been made compatible with those displayed in the Pile Driving Record, Form SCS-545, illustrated by Figure 5-3.

The example herein provides for including the elevation notes so that the record may be complete. In some cases, the determination of the elevations and cut-off may be performed as a separate operation by the survey party. For these situations, it will be necessary for the survey party chief to complete the elevation and cut-off columns in the Pile Driving Record.

It is important that a master plan be prepared showing the location of each pile required for the structure. This plan should be referred to throughout the job. The pile number recorded in the field notes should be the same as shown on the plan drawing. When the pile layout drawing does not have a number assigned to each pile, the inspector should number the field notes consecutively as each pile is driven. He also should make sure that he accurately identifies the same pile by number on the layout drawing.

It is suggested that the pile length, and diameters of the extremities, when they apply, be recorded on the same line as the pile number. This operation occurs prior to driving. At this time the number of field tests are not known. After the driving is complete, if so desired, the original dimensions of the pile may be duplicated on the same line with the final elevations, to complete the record.

Penetration determinations usually are made from temporary reference marks on the fair leads or pile, established by the inspector as the driving progresses. Measurements made by hand rule permits the driving to proceed with the minimum amount of delay.

Immediately following the last line of driving data, the inspector should include a brief summary of unusual conditions or reactions that were evident; changes in equipment or driving procedures required or any other pertinent information that may be related to the pile under consideration. (Refer to Piles and Pile Driving, Chapter 3.)

One field book or a section of a specific field book should be used for maintaining a continuous record of all pile driving operations for a given structure.

Sta.	B.S.	H.I.	F.S. or Grade Rod	Elev. or Planned Elev.	Corr. Elev.
BM#2	4.98	157.52		152.54	152.54
BM.#3			5.01	152.51	152.50
	Penetration		Comp'd	Top of Pile	
Blows	Total	Aver.	Bear	After Driving	
& Drop	(in.)	ins/blow	#'s	Rod	Elev.
PILE	#1 - FIR - CR. TR.			(8:30 - 9:10 A.M.)	
5@12	3.0	0.60	44,900		
5@12	$2\frac{1}{4}$	0.45	49,650		
5@12	$1\frac{3}{4}$	0.35	53,250	11.62	145.9
PILE	#2 - FIR - CR. TR.			(9:50 - 10:40 A.M.)	
5@12	$3\frac{1}{4}$	0.65	43,550		
5@12	$2\frac{3}{4}$	0.55	46,400		
5@12	$2\frac{1}{4}$	0.45	49,650		
5@12	2.0	0.40	51,450	11.13	146.4

SCS-29 (3-60) GPO . 1960 OF—550816

PILE DRIVING RECORD
BENT #2
CHERRY ST. BR.
STA. 10+76.20

J.R. Smith
inspector
5-20-64 7:00 A.M 4:00 P.M.
Fair - warm

Cutoff Elev.	Length of Cutoff	Length in Leads	Length in place	Dia. of Pile Butt (in)	Dia. of Pile Tip (in)
		(18.2)		(10)	(8)
145.1	0.8	18.2	17.4	10	8
		(18.5)		(11)	$(8\frac{1}{2})$
145.10	1.3	18.5	17.2	11	$8\frac{1}{2}$

Figure 5-4 Example field notes pile driving record

Engineering Notes - Test Pile Driving Record

General.

This operation which is more or less a special requirement is usually limited to one or two piles for a given site.

It is important that a detail record of the materials, equipment and driving procedures be maintained for each test pile.

Figure 5-5 illustrates headings and general layout that may be used by the inspector to document the driving operation in the engineer's field notebook. The headings and requirements illustrated are straight-forward and the necessary information should be easily acquired at the site.

It is significant that the pile number be clearly identified in the notes and also on the drawings. When the test pile is driven to proper location and becomes a part of the permanent works, it should be properly noted on the "As Built Drawings."

The inspector should include a supplementary narrative, as necessary, to clearly enumerate any unusual conditions, reactions of the pile during the driving or other observations that would be of significance in later study or evaluation.

The suggested headings and arrangement were assembled from procedures for reporting pile driving data found in the "Earth Manual," Test E-26, prepared by the Bureau of Reclamation.

Sta.	B.S.	H.I.	F.S. or Grade Rod	Elev. or Planned Elev.	Corr. Elev.
BM#2	4.98	157.52		152.54	152.54
B.M#3			5.01	152.51	152.50
PILE	#3			10:15 -	11:00 P.M
Aver. Drop ft.	Pene-tration ft.	Total blows at each ft.	Blows Per ft.	Elev. Pile Tip	
	0			150.38	
	1	0			
	2	5	5		
	3	12	7		
	4	20	8		
	5	30	10		
	6	42	12		
	~		~		
	20	600	83		
	21	695	95		
	22	811	116		
	23	990	179	127.38	
	23.1	1025		127.28	

SCS-29 (3-60)

GPO 1960 OF—550816

TEST PILE DRIVING — J.R. Smith
RECORD - BENT #2 — Inspector
CHERRY ST. BRIDGE — 5-26-64 7:00 A.M. 4:00 P.M.
STA. 10+76.20 — Cloudy - warm

Make Model Hammer: Vulcan - Mod. 1
Type of Hammer: Single Action - Stm.-Air
Wt. of Hammer: 5000 lbs.
Aver. Blow/minute: 55, stroke or fall 36"
Manuf. Rating "E": 15,000 ft.lbs.
Pile Length-total: 28' Dia. Butt: 13" Tip: 9"
Pile Length After Cutoff: 24.5'
Pile Length in ground: 23.0'
Pile Dia. @ Cutoff: 12"; At ground: $11\frac{3}{4}$"
Kind & type Pile: Round Cresote
Treated Fir Timber, straight, peeled all knots Smooth - point steel driving shoe

OBSERVATIONS FOR 1" PENETRATION

6 blows/in @ 18'	12 blows/in. @ 22'-6"
7 blows/in. @ 19'-6"	14 blows/in. @ 22'-9"
9 blows/in @ 21'	20 blows/in. @ 23'
11 blows/in. @ 22'	Driving Stopped at 21 blow/in.

Figure 5-5 Example field notes test pile driving record

Engineering Notes - Test Pile Loading Record

General.
The ability of foundation pile to support a vertical load may be determined by applying loads to a specific pile in a prescribed manner.

The load-settlement data that results from the field test, and the apparatus and procedures used should be reported in a concise and complete manner.

Figure 5-6 illustrates headings and general layout that may be used by the inspector to document the incremental load-settlement results in the engineer's field notebook. This record, including the related data, is supplemental to the Test Pile Driving Record shown in Figure 5-5.

The inspector should give special attention to the detail requirements for making the test as specified, and in arranging to take and record the results at proper time intervals.

A narrative with photos or drawings should be included, when required, to show equipment layout and to document unusual conditions that occur during the load test.

The suggested headings and arrangement were assembled from procedures for reporting test pile loading data presented in the "Earth Manual," Test E-26, prepared by the Bureau of Reclamation.

Sta.	B.S.	H.I.	F.S. or Grade Rod	Elev. or Planned Elev.
Date & Time	Elapsed Time hrs.-min	Load (Tons)	Settlement (ins.)	Remarks
5-28-64 8:00A.M	0:00	0.0	0.000	
	0:02	12.5	"	
	:10	"	"	
	:20	"	"	
	:40	"	"	
	1:00	25.0	0.003	
	:01	"	"	
	:10	"	"	
	:20	"	"	
	:40	"	"	
	2:00	"	"	
	3:00	37.5	0.006	For illustr. time inter: 01 10, 20, 40 not shown
	4:00	50.0	0.008	
	5:00	62.5	0.011	
	6:00	75.0	0.013	
	7:00	100.0	0.018	
	30:00	"	"	No reading 7-30 hours
	30:01	50.0	0.012	
	32:00	25.0	0.010	Time intervals not shown
	33:00	10.0	0.007	
	34:00	0.0	0.005	Loading Ended 5-29-64

SCS-29 (3-60)

GPO . 1960 OF—550816

TEST PILE LOADING — J.R. Smith - Inspector
RECORD - BENT #2 — R.W. Brown - Recorder
CHERRY ST. BRIDGE — 5-28-64
STA. 10+76.20 — Clear - Warm

PILE NUMBER 3

Date Pile Driven: 5-26-64

Kind & type Material: Round Creosote treated Fir timber

Condition of Pile: Smooth & sound at cutoff

Elev. - Butt: 151.78 Tip: 127.28

Ground Elev. @ Pile: 150.2

Method of measuring settlement: Engr's Level & Rod w/Vernier

Method of loading & Equip.:

Reaction load consisting of box filled with Sand, Supported by timbers and steel I beam Cribbing.

Load applied to pile by calibrated hydraulic jack.

Four black and white photo's taken of test equipment

Figure 5-6 Example field notes test pile loading record

Quantity Computations - (SCS-528, 529, 344A & 522A)

Earthwork

General.

There are a number of acceptable methods in general use for computing earth quantities.

The most appropriate formula or method to use will depend on the topography of the ground at the time the original and the final cross sections of the area are taken. Final quantities of earthwork are normally determined by actual calculations of the cross sectional end areas.

The planimeter may be used for determining end areas for calculating quantities for partial payments. It may also be used for final quantity determination when such procedure, in the opinion of the State Conservation Engineer, will result in sufficient accuracy for the specific items of work.

When the planimeter is used for final quantity determination, special emphasis should be given to:

(1) Determining the correct constant reading for the equipment.

(2) Making sure that at least three separate measurements are made of each sectional area which check within reasonable tolerance.

(3) Using the average reading for area calculation, and

(4) Having all areas checked by a second party to verify the accuracy of the measurement.

End areas for all earthwork computations are calculated in square feet. The average-end-area method is the method most commonly used to determine the volume between two cross sections or end areas. This method may be expressed by the following formula:

$$V = L \frac{(A_1 + A_2)}{54}$$

where V is the volume in cubic yards of the prismoid between cross sections having areas in square feet of A_1 and A_2 separated by a distance L feet. Figure 5-11 lists conversion factors in L distances from 1 to 100 feet which, when multiplied by the sum of the end areas A_1 and A_2, give V in cubic yards.

Formula for Computing End Areas

(1) Level Cross Sections.

The end area A in square feet may be calculated by the formula

$$A = C\left(d + \frac{W}{2}\right)$$

where C - is the center cut or fill in feet

d - is the distance from centerline to either slope stake, in feet

and W - is the width of top of fill or bottom of channel, in feet (level section).

(2) Three level section

The end area A in square feet may be calculated by the formula:

$$A = \frac{W}{4}(h_1+h_2) + \frac{C}{2}(d_1+d_2) \quad \text{(see sketch below)}$$

where W = width of top of embankment, or bottom of cut in feet (level section)

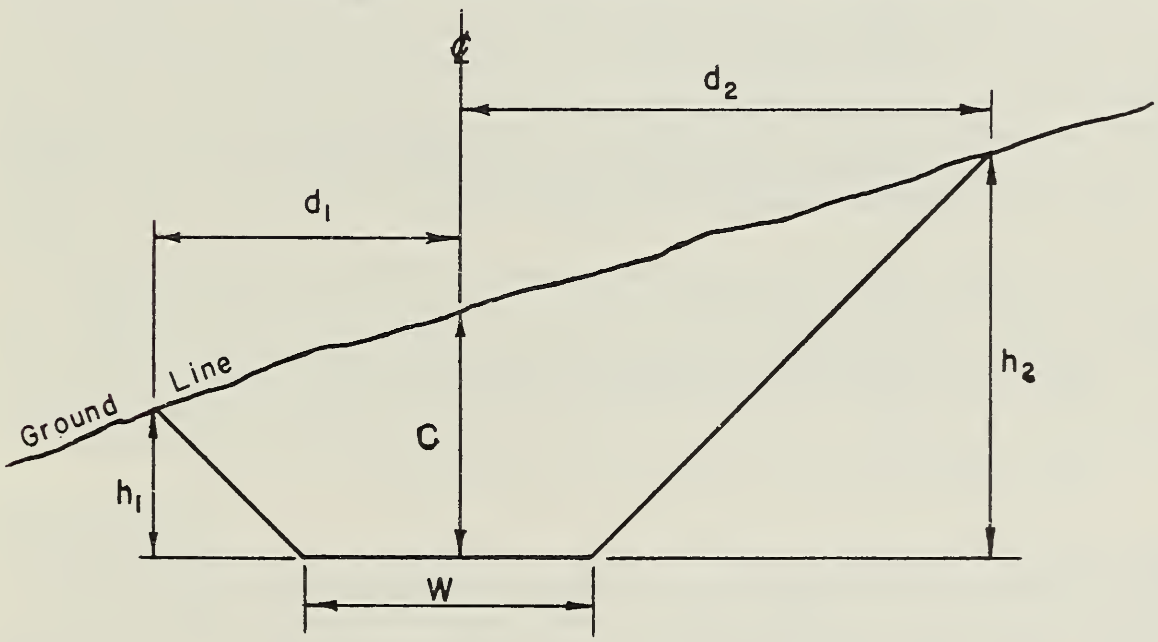
h_1 = cut or fill, left of centerline, in feet

h_2 = cut or fill, right centerline, in feet

C = cut or fill at centerline, in feet

d_1 = distance left centerline to slope stake, in feet

d_2 = distance right centerline to slope stake, in feet



computations for cross sections using methods (1) or (2) may be recorded on SCS 344a, Tabular Computation Sheet, or on SCS-522A Computation Sheet (see Exhibits 5-13 and 5-14).

(3) Irregular Cross Section.

The following procedure is an adaptation of the coordinate method of computing areas. Commonly referred to as the double end area method. Level notes for excavated channels or embankments are recorded in the field notes in the regular manner, cut (C) or fill (F) referenced to the finish datum (base grade) and the distance right or left of centerline. The level notes must also contain the distance to each edge of the base when in cut, or outside shoulder line for fills. The end area of the cross section in square feet may be determined by performing the following steps.

Procedure:

(1) Use minus signs for distances to the left of center; plus signs for distances to the right of center.

(2) Use minus sign for any vertical distance below the base grade in cuts or above base grades in fills.

(3) Start at any point; use every value of the numerator in order, proceeding clockwise or anti-clockwise around the figure.

(4) Multiply each value of the numerator by the difference, using algebraic values, of the distances of the point ahead and the point next back.

(5) Find the algebraic sum of all these quantities and divide by 2.

This rule applies to all cross sections.

If a centerline does not exist as such, establish a reference line for denoting distances left and right.

The use of this method with some of the variations that are used to compute areas of irregular sections are illustrated in Figure 5-7, 5-8, 5-9 and 5-10. Form SCS-528 "Earthwork Computation Sheet" used in the above-mentioned figures, has been prepared for use in the field to record the cross section notes, the method and the results of end area and volume calculations. The column headings for the last four vertical columns (use as needed) should be filled in to properly identify the method used to determine the volume quantities.

Figure 5-7 illustrates an embankment cross section and Figure 5-8 illustrates a cross section in cut. Both figures include the grade rod and distance data for each elevation point and also sample calculations to illustrate the procedural steps (1) through (5) as outlined above.

Figure 5-9 although similar in format and content to Figure 5-7 illustrates an alternate procedure that may be used. Sample calculations and the suggested detail operations are also shown.

Figure 5-10 is similar in format and content to Figure 5-8. The procedure illustrated often referred to as the criss-cross or diagonal method is recognized for its simplicity. The method is also well adapted to calculating machine operations. The positive products (considering data along solid lines) are accumulated, then without clearing the product dial the machine is thrown into reverse and reverse multiplication is carried forward for the negative quantities, (data along dashed lines). The remainder at the end of the calculation is the double end area of the cross section.

The use of this method should be restricted to sections that are represented by positive grade rod data. Cross sections that have a small standard quantity of excavation or fill that would normally be represented by a negative grade rod (above or below base grade line) can be computed separately and included in the final quantity, thus increasing the adaptability of this method.

For sections entirely in cut or fill the axes are usually the center line and the finish elevation top of embankment or bottom of cut. For side hill sections involving cut and fill quantities, it may be advantageous, for calculation purposes, to shift the vertical axis to the point of zero cut-fill (correcting horizontal field note data accordingly) since cut and fill quantities are commonly accumulated separately.

The headings for each computation sheet should be properly filled out and complete identification of the structural feature for which quantities have been computed, should be added to the heading. Make separate computation sheets for each bid item or element of a bid item as required.

Borrow Areas.

Quantities of excavation removed from borrow areas may be computed by dividing the surface area into squares, rectangles or triangles using the level elevations for each corner of the original face and the elevation of the same point after excavation, or before and after cross section may be used to compute end areas and volumes, using the same procedure outlined for other earthwork computations. Under some circumstances, it may be found desirable to use a combination of both methods.

For normal conditions of excavation and finish of completed borrow area, the cross section method should prove to give adequate accuracy for quantity determination.

Computation data should be recorded on appropriate SCS computation forms, including adequate headings and site identification.

Concrete

Final quantities of concrete in place should be computed to the limits shown in the drawings or as staked. Calculations may be simplified in many instances by subdividing the structure elements into components of geometrical shape which may be computed by mathematical formula. Each segment should be computed to hundredths and the final total quantity rounded to the nearest tenth cubic yard, unless specified otherwise.

All sketches, formula and calculations may be recorded on SCS-522A, Computation Sheet.

Steel

Final weights or quantities for steel may be determined by careful verification of size, length and total weight recorded on invoices, as compared to the drawings and the placement records, or quantities may be computed using unit weight tables for the shape furnished, multiplied by the actual lengths placed and measured in accordance with specifications and the drawings.

All computations and records for steel quantities should be properly identified and documented on Form SCS-344A or 522A. Properly approved invoices or delivery slips may be filed as supporting data.

Other Items

Quantity determinations for other contract items such as pipe, timber and lumber, revetment, asphalt concrete, etc. should be carefully measured in the units specified in the contract. All calculations as required for quantity determination or supporting data for estimates or final payment should be recorded on Standard Forms SCS-522A, 344A or other approved Service record forms.

SCS-528
(Rev. 11-19-64)

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

EARTHWORK COMPUTATION SHEET

LOCATION Winona, Oklahoma OWNER Winona F. C. Dist. CONTRACTOR Wilder Construction Co. CONTRACT NO. WC-82-63

WATERSHED Washita River ITEM Embankment Item #5 COMPUTED BY Joe Smith DATE 1-22 19 63

SUB-WATERSHED Winona Creek SITE NO. 5 FINAL QUANTITY ____ CU. YDS. ____ CHECKED BY M. H. Brown DATE 1-25 19 63

STATION	* Lt.						* ℄		* Rt.				Double E.A.	(Σ E.A.)2	DISTANCE	(VOL. CU.FT.) 4	VOL.-YD.³ (FT.³/108)
5+00	0.0	0.3	20.0	20.0	30.4	32.0	38.0	38.0	32.4	-0.3	0.0						
	-0.0	-10.0	-60.0	-72.5	-98.5	-45.0	+0.0	+40.0	+91.0	+10.0	+ 0.0		7,693.3				
														15,918.8	50	795,940.0	7,369.8
5+50	0.0	0.3	20.0	20.0	36.0	36.1	37.5	35.7	34.6	-0.3	0.0		8,225.5				
	-0.0	-10.0	-60.0	-72.5	-112.5	-50.0	0.0	+51.0	+96.5	+10.0	+0.0						

SAMPLE CALCULATIONS:

Emb. Sta 5+00

		+		−
0.3	[-60.0 - (-0.0)] =		0.3 x (-60.0) = 18.0	
20.0	[-72.5 - (-10.0)] =		20.0 x (-62.5) = 1250.0	
20.0	[-98.5 - (-60.0)] =		20.0 x (-38.5) = 770.0	
30.4	[-45.0 - (-72.5)] = 30.4	x 27.5 = 836.0		
32.0	[+0.0 - (-98.5)] = 32.0	x 98.5 = 3152.0		

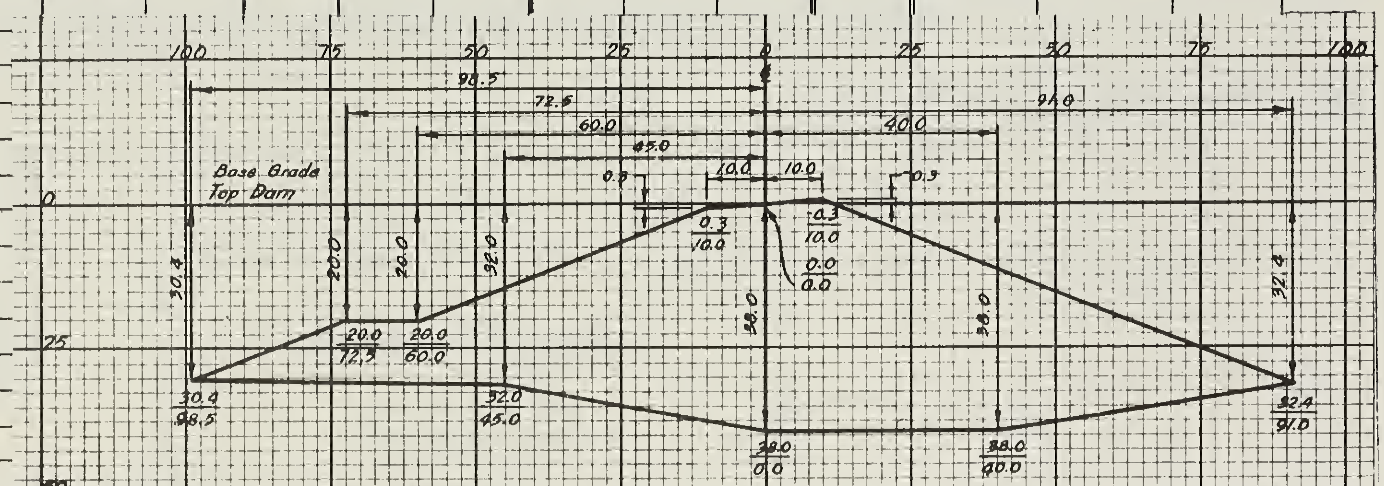
Sta. 5+00 (Continued)

		+	−
38.0	[+40.0 - (-45.0)] = 38.0	x 85.0 = 3,230.0	
38.0	[+91.0 - (+0.0)] = 38.0	x 91.0 = 3,458.0	
32.4	[+10.0 - (+40.0)] =		32.4 x (-30.0) = 972.0
-0.3	[+0.0 - (+91.0)] = -0.3	x (-91.0) = 27.3	

Σ (+) = 10,703.3

Σ (-) = 3,010.0

E.A. x 2 = 7,693.3



* PROVIDE APPROPRIATE HEADINGS FOR USE OF OFFSET OR ℄ BASELINE

Figure 5-7

SCS-528
(Rev. 11-19-64)

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

EARTHWORK COMPUTATION SHEET

LOCATION Winona, Oklahoma OWNER Winona F. C. Dist. CONTRACTOR Wilder Construction Co. CONTRACT NO. WC-82-63

WATERSHED Washita River ITEM Access Road Item #13 COMPUTED BY Joe Smith DATE 1-22 19 63

SUB-WATERSHED Winona Creek SITE NO. 5 FINAL QUANTITY ______ CU. YDS. ______ CHECKED BY M. H. Brown DATE 1-25 19 63

STATION			* Lt.				* ℄			* Rt.			Double E.A.	ΣE.A./2	DISTANCE	FACTOR	VOLUME CU. YDS.
2+50		0.0 0.0	0.0 -16.0	-1.0 -18.0	9.0 -38.0	11.0 -18.0	9.0 0.0	5.4 30.8	-1.0 18.0	0.0 16.0	0.0 0.0		991.2				
														1,039.6	50	.92593	962.6
3+00			0.0 0.0	0.0 -16.0	-1.0 -18.0	10.0 -40.0	10.5 0.0	6.2 32.4	-1.0 18.0	0.0 16.0	0.0 0.0		1088.0				

SAMPLE CALCULATIONS:

Cut Sta: 2+50

+   −

-1.0 [-38.0 - (-16.0)] = -1.0 x (-22.0) = 22.0

9.0 [-18.0 - (-18.0)] = 9.0 x 0.0 = —

11.0 [0.0 - (-38.0)] = 11.0 x 38.0 = 418.0

9.0 [+30.8 - (-18.0)] = 9.0 x 48.8 = 439.2

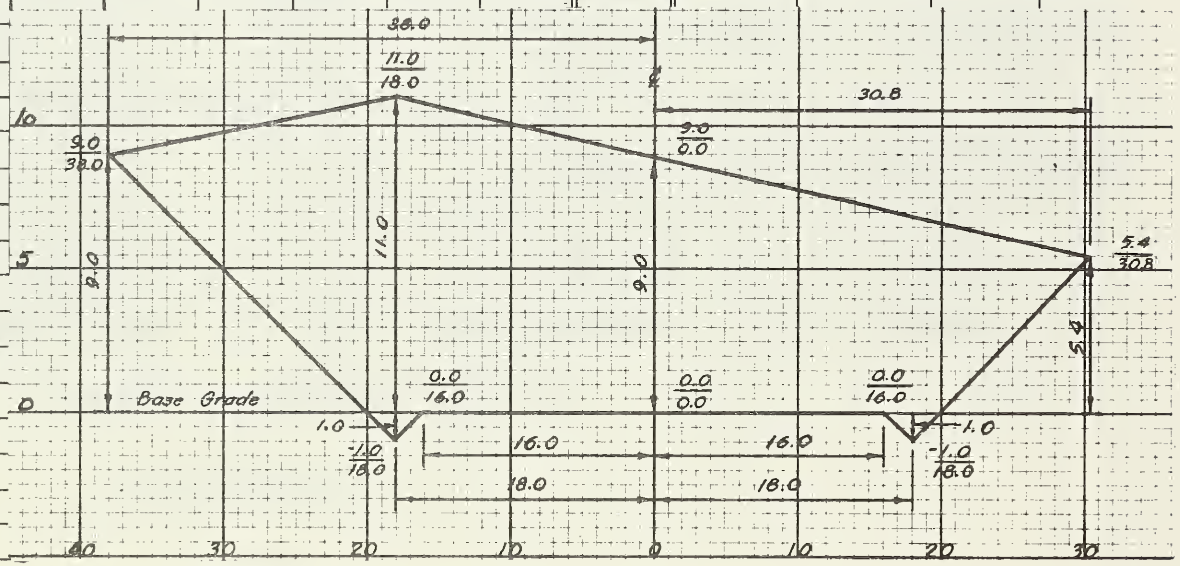
5.4 [+18.0 - (-0.0)] = 5.4 x 18.0 = 97.2

-1.0 [+16.0 - (+30.8)] = -1.0 x (-14.8) = 14.8

Σ(+) = 991.2

Σ(-) = 0

E.A. x 2 = 991.2



* PROVIDE APPROPRIATE HEADINGS FOR USE OF OFFSET OR ℄ BASELINE

Figure 5-8

SCS-528
(Rev. 11-19-64)

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

EARTHWORK COMPUTATION SHEET

LOCATION Winona, Oklahoma OWNER Winona F. C. Dist. CONTRACTOR Wilder Construction Co. CONTRACT NO. WC-82-63

WATERSHED Washita River ITEM Embankment Item #5 COMPUTED BY Joe Smith DATE 1-22 19 63

SUB-WATERSHED Winona Creek SITE NO. 5 FINAL QUANTITY ____ CU. YDS. ____ CHECKED BY M.H. Brown DATE 1-25 19 63

STATION	* Lt.					* ℄		* Rt.					Double E.A.	(Σ E.A.)2	DISTANCE	(VOL. CU. FT.) 4	VOLUME YD³ (FT³/108)
2+00(1)	0.0	0.3	20.0	20.0	30.4	32.0	38.0	38.0	32.4	-0.3	0.0						
(2)	0.0	-10.0 +	-60.0 +	-72.5 +	- 98.5 +	-45.0+	0.0	+40.0 -	+91.0-	+10.0 -	0.0						
(3)	-10.0	-60.0	-62.5	-38.5	+ 27.5	+98.5	+85.0	+91.0	-30.0	-91.0	-10.0						
(4)	-0.0	-18.0	-1250.0	-770.0	+836.0	+31520	+3230.0	+3458.0	-972.0	+27.3	-0.0		7,693.3				
														15,918.8	50	795,940.0	7,369.8
2+50	0.0/0.0	0.3/10.0	20.0/60.0	20.0/72.5	36.0/112.5	36.1/50.0	37.5/0.0	35.7/51.0	34.6/96.5	-0.3/10.0	0.0/0.0		8,225.5				

PROCEDURE:

(1) Represents fill heights to constructed grade (in feet). Record as minus (-) quantity when above or below base grade.

(2) Represents horizontal distances Rt. and Lt. of ℄ (in feet). For each point Lt. of ℄ place a (-) sign preceeding the number and a (+) sign immediately following the number. To the Rt. of ℄ reverse the procedure place + sign as a prefix, and a (-) sign as a suffix. Include the 0.0 points, both extremities of the x - section.

(3) Represents the algebraic difference in distance between the point immediately ahead and point next back, using the signs adjacent to the point under consideration (* See example below.)

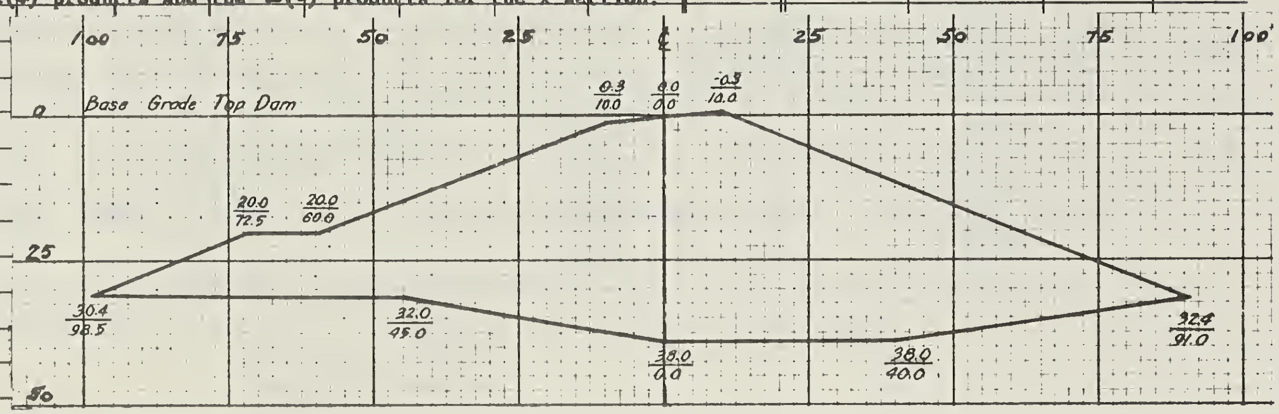
The $\Sigma(+)$ distances $-\Sigma(-)$ distances = 0.

(4) Determined by multiplying (1) x (3) in each vertical column using the correct algebraic sign for each product.

Double E.A. = The difference between the $\Sigma(+)$ products and the $\Sigma(-)$ products for the x-section.

*

(1)	0.3	20.0	20.0
(2)	-10.0+	-60.0+	- 72.5+
(3)		-62.5	
			- 72.5
			+ 10.0
			- 62.5



* PROVIDE APPROPRIATE HEADINGS FOR USE OF OFFSET OR ℄ BASELINE

Figure 5-9

SCS-528
(Rev. 11-19-64)

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

EARTHWORK COMPUTATION SHEET

LOCATION Winona, Oklahoma OWNER Winona F. C. Dist. CONTRACTOR Wilder Construction Co. CONTRACT NO. WC-82-63

WATERSHED Washita River ITEM Emergency Spillway Item #4 COMPUTED BY Joe Smith DATE 1-22 19 63

SUB-WATERSHED Winona Creek SITE NO. 5 FINAL QUANTITY ______ CU. YDS. ______ CHECKED BY M. H. Brown DATE 1-25 19 63

STATION	* Lt.				* ℄			* Rt.		Double E.A.	(ΣE.A.)2	DISTANCE	(VOL. CU. FT.) 4	VOLUME CU. YDS
2+00	0.0 / 0.0	0.0 / 20.0	9.0 / 38.0	11.0 / 18.0	9.0 / 0.0	5.4 / 30.8	0.0 / 20.0	0.0 / 0.0		983.2				
											2067.4	50	103,370.0	957.1
2+50		0.0 / 0.0	0.0 / 20.0	10.0 / 40.0	10.5 / 0.0	6.2 / 32.4	0.0 / 20.0	0.0 / 0.0		1084.2				

SAMPLE CALCULATIONS:

Sta. 2+00

+		-	
9.0 x 20.0 =	180.0	9.0 x 18.0 =	162.0
11.0 x 38.0 =	418.0		
9.0 x 18.0 =	162.0		
9.0 x 30.8 =	277.2		
5.4 x 20.0 =	108.0		

Σ (+) = 1145.2

Σ (-) = 162.0

E.A.x2 = 983.2

PROCEDURE:

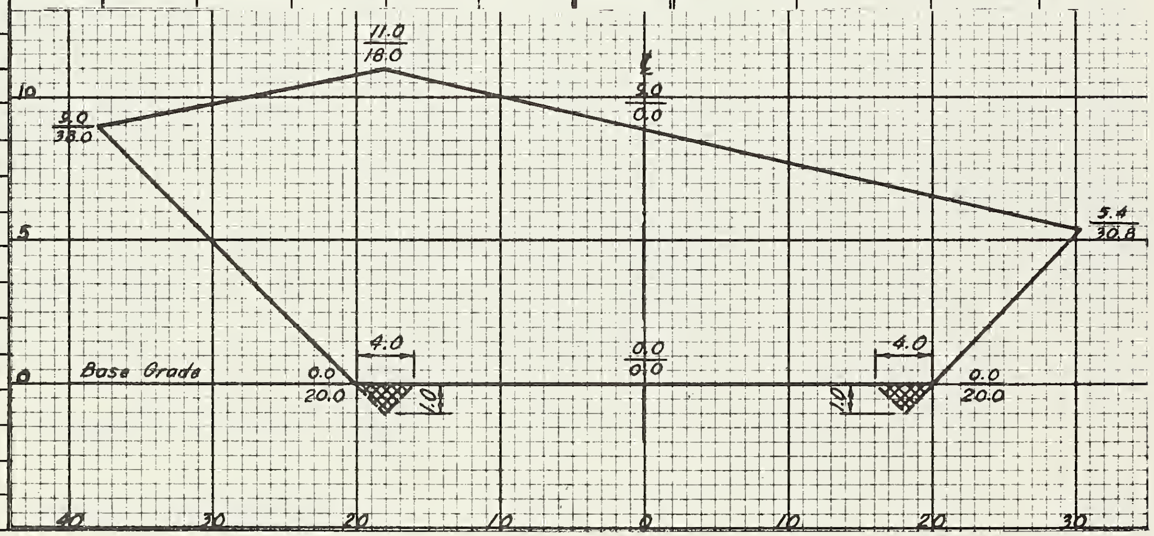
Multiply grade rod x adjacent distance from ℄ as indicated by the solid diagonal lines, and add the products - all positive (+)

Multiply as shown by the opposite diagonal dashed line and add the products — all negative (-)

The difference gives the double end area.

NOTE:

Minor quantities of C. or F. that are performed to a uniform section, and which normally would be represented by a (-) grade rod in the calculations may be computed as separate quantities to complete the total E. A. or volume: For example, ditch sections this figure.



* PROVIDE APPROPRIATE HEADINGS FOR USE OF OFFSET OR ℄ BASELINE

Figure 5-10

EARTHWORK COMPUTATION TABLE

Feet Between X-Sec's	Constant Computing Factor	Feet Between X-Sec's	Constant Computing Factor	Feet Between X-Sec's	Constant Computing Factor	Feet Between X-Sec's	Constant Computing Factor
1	.01852	26	.48148	51	.94444	76	1.40741
2	.03704	27	.50000	52	.96296	77	1.42592
3	.05556	28	.51852	53	.98148	78	1.44444
4	.07407	29	.53704	54	1.00000	79	1.46296
5	.09259	30	.55555	55	1.01852	80	1.48148
6	.11111	31	.57407	56	1.03704	81	1.50000
7	.12963	32	.59259	57	1.05555	82	1.51852
8	.14815	33	.61111	58	1.07407	83	1.53704
9	.16667	34	.62963	59	1.09259	84	1.55555
10	.18519	35	.64815	60	1.11111	85	1.57407
11	.20370	36	.66666	61	1.12463	86	1.59259
12	.22222	37	.68518	62	1.14815	87	1.61111
13	.24074	38	.70370	63	1.16667	88	1.62963
14	.25926	39	.72222	64	1.18518	89	1.64815
15	.27778	40	.74074	65	1.20370	90	1.66666
16	.29630	41	.75926	66	1.22222	91	1.68518
17	.31481	42	.77778	67	1.24074	92	1.70370
18	.33333	43	.79629	68	1.25926	93	1.72222
19	.35185	44	.81481	69	1.27777	94	1.74074
20	.37037	45	.83333	70	1.29630	95	1.75926
21	.38889	46	.85158	71	1.31481	96	1.77778
22	.40741	47	.87037	72	1.33333	97	1.79629
23	.42593	48	.88889	73	1.35185	98	1.81481
24	.44444	49	.90741	74	1.37037	99	1.83333
25	.46296	50	.92593	75	1.38889	100	1.85185

Note: Sum of End Areas in sq. ft. X Constant = Cu. yds. per Sta.

Figure 5-11

SCS-529
(REV. 11-19-64)

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

EARTHWORK COMPUTATION SHEET

LOCATION Lancaster, Ohio	OWNER John Doe		
W[illegible]ED Upper Hocking	SUB-WATERSHED Part C	SITE NO. 9	
CON[illegible]ACTOR Henry Roe	COMPUTED BY W. L. Shriner	DATE 9/18/63	
ITEM Outlet Channel Excavation	CHECKED BY McCandlish	DATE 9/19/63	
CONTRACT NO. 12-10-330-43	ESTIMATE 3248 CU. YDS.	ACTUAL 3098 CU. YDS.	

X-Sec. Scale-1"= 10' Vert. / 10' Hor. (End area's by planimeter - Machine Constant 1.00 = 1 sq. in.)

STATION	END AREA SQ. IN.	END AREA SQ. FT.	SUM OF END AREAS SQ. FT.	DISTANCE IN FEET	SECTION PRODUCTS CU. FT.	VOLUME CU. YD.	REMARKS
12+40	0	0					
			245	60	14700		
13+00	2.45	245					
			495	50	24750		
13+50	2.50	250					
			507	50	25350		
14+00	2.57	257					
			497	50	24850		
14+50	2.40	240					
			316	100	31600		
15+50	0.76	76					
			186	50	9300		
16+00	1.10	110					
			164	100	16400		
17+00	0.54	54					
			139	50	6950		
17+50	0.85	85					
			187	50	9350		
18+00	1.02	102					
			102	40	4080		
18+40	0	0					
				Total	167,330 / 2 x 27	= 3098 c.y.	
			S A M P L E				

SHEET ______ OF ______ SHEETS

Figure 5-12

Fill in the proper headings; show project, job site,

names of computor and checked by - dates, etc.

similar to Figure 5-12.

Figure 5-13

COMPUTATION SHEET
SCS-522A REV 5-58

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

STATE		PROJECT		
BY	DATE	CHECKED BY	DATE	JOB NO.
SUBJECT				SHEET ____ OF ____

Side Calculation

Sketches

Formulas

Calculations

Quantities

Figure 5-14

Bid Item Record Sheet - (SCS-546)

General.
The Bid Item Record Sheet is an optional form, which has been prepared for use by the field construction office to maintain a complete record of all approved work for each bid item, or extra items of work, included in the contract.

The Bid Item Record Sheet is posted daily, as required, to show items or quantities of work as they are computed and checked for partial or final payment. Daily posting also include delivered materials or equipment approved for payment, and deliveries and placement of acceptable materials, that may be measured, as specified, in the delivery process. For example, rock riprap or base rock by the ton or load count, or water by meter measure.

Documentary evidence should support items posted to the Bid Item Record Sheet. This evidence includes: checked and approved calculations, contract modifications, contractors request for payment, daily scale weight sheets, meter records, inspectors count reports, or other acceptable records.

Properly maintained, the Bid Item Record Sheets reflect the status of work accomplished to date and the amount of payment for each item of work.

The quantity and amount totals of Estimate This Period and Estimate Completed to Date may be used to prepare the SCS-49, Partial Payment Report. Partial or final payment quantities and amounts shown on the Bid Item Record Sheets should check with the SCS-49 report.

The Bid Item Records Sheets may be kept in a three ring binder for easy access and filing. Proper identification on the outside of the binder is desirable to facilitate office operations.

Supporting calculations, sketches and duplicate field notes should be filed chronologically in a Bid Item Computation File. The Computation File may be separate folders identified with the bid item numbers and equipped with acco type fasteners to anchor the filed material, or a large three-ring binder with dividers.

All supporting records will clearly show the item number, (Bid Item Record Sheet Form) date, and the name of the person who posted entries on the Bid Item Record Sheet.

Upon receipt of the contract schedule of prices, the Government Representative will be responsible for preparing and filing a separate Bid Item Record Sheet for each bid item or sub-item included in the contract.

Procedure.
Procedure for preparation and use of the form is as follows: (Refer to the Bid Item Record Sheet Form, Figure 5-15).

Heading.--Identify the project by contract number and structure name or number on each sheet, regardless of the number of sheets required for each bid item.

Item no.--Enter bid item number as it appears on the bid schedule. (The same number may also be entered as a reference in the lower left corner.)

Unit price.--The contract unit price or lump sum for the item.

Description.--Use terminology as contained in the bid schedule, supplemented as desired for clarity.

Unit.--The contract unit of measure for the bid item.

+ or - 25%.--For unit price items, multiply the contract estimate quantity by 1.25 and 0.75 and post the result in the appropriate space.

Form.

Date.--Post the date of entry of items or partial payment estimate. Continue on same sheet accumulating data from pay estimate to pay estimate, until completion of the item of work. Use as many lines and sheets as required. Maintain all sheets in the three-ring binder.

Description of entry.--Brief reference identifying the entry.

Reference file.--Cross reference the file or location of data supporting the entry.

Authorized contract award.--Enter the contract estimated quantity and amount for the item.

Authorized change.--Record as + or - quantity and show authorized changes in amount of the contract.

Authorized total.--Post the modified authorized contract quantity and amount in accordance with the authorized change to reflect to date status of contract item.

Estimate this period.--Post the unit amounts, partial or final as of date the quantity calculations are checked and approved. Other entries will be made as supporting evidence is provided; i.e. approved materials delivered to the site not installed, approved lump sum amounts or approved materials delivered and placed which are recorded in units that correspond to the contract unit of measurements.

The partial payment quantity and amount is the total of entries posted since the last pay estimate. Quantities for a phase of the item that is not completed this pay period and hence will appear in later estimates should be entered in parenthesis - only quantity, not amount. Quantities shown otherwise indicate that this is the final quantity.

Estimate complete to date.--Quantity and amount are the sums of the estimated this period and the estimate complete to date for the previous partial payment.

Percent complete.--Actual - Ratio of amount in dollars of pay item completed to date, to the authorized total amount.

Schedule - The percent complete shown in the contractor's construction schedule, as of the date of partial payment estimate.

The following example will illustrate the use of the Bid Item Record Sheet form:

Item 3.
Excavation Common (see Figure 5-15). Heading - Name of Structure.

Entry 5/1.--Contract Estimate from bid schedule in Authorized Contract - record yards and dollars - first order of business.

5/15.--Foundation stripping, quantities computed and checked, entered Estimate This Period - quantity and dollars.

5/20.--Contract modification #1 approved for increasing foundation excavation for the principal spillway - show quantity and amount under Authorized Change, and reflect correction of authorized contract as awarded, in column Authorized Total, quantity and amount.

5/31.--As of end of pay period calculations for principal spillway foundation were approved, quantity and amount entered Estimate This Period. Also estimate of excavation - quantity in cut-off trench partially complete - amount entered in parenthesis - Estimate This Period.

5/31.--Partial payment #1 - Estimate This Period, sum of quantity and amount columns - and carried into the respective columns - Estimate Complete To Date. Also record percent completed, actual and scheduled in the percent Complete Columns, so progress of the work can be evaluated.

Double line space occupied by the Partial Payment line, so it will stand out. Ink of a contrasting color may be used. Skip a line and continue entries.

6/15.--Computations were approved for quantities of excavation in the tail-ditch-enter yards and dollars in Estimate This Period.

6/25.--Foundation material in cutoff trench was found to be unsatisfactory, and it was estimated that the additional excavation required would exceed the +25 percent limit for the bid item. Agreement was reached with the contractor to move excess, as determined by final cross sections, for $0.50/cu.yd. Contract Modification #2 approved

for price per cu. yd. for excess. Unit price entered under Authorized Change for future use in final calculation.

6/29.--Quantities for completed cut-off trench were approved; compute entry as follows: Accumulate total quantity for previous partial payment and quantities, which are due for Partial Payment #2:

Partial payment #1	4825 c.y.
6/15	210 c.y.
6/29 computed total	2875 c.y.
6/30 total	7910 c.y.

Recognize that the +25 percent clause requires the contractor to excavate up to 7500 c.y. at original contract price. Therefore, 410 c.y. will be paid for under Contract Modification #2 agreement @ $0.50.

To complete the record sheet - 6/29 record under Authorized Change + 500 c.y. - enter 7500 c.y. under Authorized Total (7000 + 500) and in Estimate This Period, record 2465 c.y. (2875 - 410).

6/30.--Under the authority of Contract Modification #2 - post + 410 c.y. to Authorized Change column, and show total of 7910 in Authorized Total column and also enter 410 c.y. @ $0.50 in Estimate This Period.

6/30.--Partial payment #2 - Find total for all entries of quantity and amount under column Estimate This Period - 3085 c.y. and $1275.00 respectively.

Add these totals to quantity and amount reported under Partial Payment #1 for total under Estimate Completed to Date.

Since this completes the payment for this item, it should be so indicated on the record form.

Examples for recording earth embankment and concrete items are shown in Figures 5-16 and 5-17. The procedure for making entries and keeping the record is similar and may be easily followed to become more familiar with the use of the form.

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(Rev. 11-19-64)

BID ITEM RECORD SHEET

Item No. 3 Unit Price 0.40
Description Excavation - Common
Unit Cu. yd. + 25% 7,500.0
− 25% 4,500.0

Contract No. 1
Structure Dam No 2

DATE 1961	DESCRIPTION OF ENTRY	REF FILE SUPPLEMENT DATA	AUTHORIZED CONTRACT AWARD QUANTITY	AUTHORIZED CONTRACT AWARD AMOUNT	AUTHORIZED CHANGE QUANTITY	AUTHORIZED CHANGE AMOUNT	AUTHORIZED TOTAL QUANTITY	AUTHORIZED TOTAL AMOUNT	ESTIMATE THIS PERIOD QUANTITY	ESTIMATE THIS PERIOD AMOUNT	ESTIMATE COMPLETED TO DATE QUANTITY	ESTIMATE COMPLETED TO DATE AMOUNT	% COMPLETE ACT	% COMPLETE SCHED
5/1	Contract Estimate	Bid Sch.	6,000.0	2400.00		-		-						
5/15	Stripping - Found.	Comp. File/3							1210.0	484.00				
5/20	C.M. #1, Found. Pr. Spwy	C.M. File			+1000.0	+400.00	7000.0	2,800.00						
5/31	Found. Pr. Spwy - Compl.	Comp/File/3							3,015.0	1206.00				
5/31	Cut-off trench	Comp File/3							(600.0)	240.00				
5/31	Partial Payment #1		6,000.0	2,400.00	+1000.0	400.00	7,000.0	2800.00	4825.0	1930.00	4825.0	1930.00	69	50
6/15	Tail Ditch - Complete	Comp. File/3							210.0	84.00				
6/25	C.M #2 - Cut-off trench	C.M. File			over 0.50 /	25% @ C.Y.								
6/29	Cut-off trench - Compl.	Comp File/3			+500.0	+200.00	(+25%) 7,500.0	3,000.00	2465.0	986.00				
6/30	Excess - 25% Cl. @ 0.50	C.M File Comp/3			+410.0	+205.00	7,910.0	3,205.00	410	205.00				
6/30	Partial Payment #2		6,000.0	2,400.00	+1910.0	+805.00	7,910.0	3,205.00	3085.0	1275.00	7,910.0	3,205.00	100	85

Item 3; 100 % Complete
6/30/1961 P.P. #2

3 Item No.

Figure 5-15

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BID ITEM RECORD SHEET

Item No. 4 Unit Price 0.40
Description Embankment - Zone 1
Unit Cu. Yd. + 25% 85,125.
− 25% 51,075.

Contract No. 1
Structure Dam No 2

DATE	DESCRIPTION OF ENTRY	REF. FILE SUPPLEMENT DATA	AUTHORIZED CONTRACT AWARD		AUTHORIZED CHANGE		AUTHORIZED TOTAL		ESTIMATE THIS PERIOD		ESTIMATE COMPLETED TO DATE		% COMPLETE	
1961			QUANTITY	AMOUNT	QUANTITY	AMOUNT	QUANTITY	AMOUNT	QUANTITY	AMOUNT	QUANTITY	AMOUNT	ACT	SCHED
5/1	Contract Estimate	Bid Sched	68,100.0	27,240.00										
5/20	Princ. Spwy. Found.	Comp. File/4							3,015.0	1206.00				
5/31	Cut-off trench	Comp. File/4							(1210.0)	484.00				
5/31	Partial Payment #1		68,100.0	27,240.00		-0-		-0-	4,225.0	1690.00	4225.0	1690.00	6	10
6/17	Cut off trench	Comp./File/4							2275.0	910.00				
6/31	Found. Strip. Area	Comp. File/4							1210	484.00				
6/31	Dam Zone 1	Comp File/4							(4,200.0)	1,680.00				
6/31	Partial Payment #2		68,100.0	27,240.00		-0-		-0-	7,685.0	3,074.00	11,910.0	4,764.00	18	25
7/31	Dam - Zone #1	Comp. File/4							(15,600.0)	6,240.00				
7/31	Partial Payment #3		68,100.0	27,240.00		-0-		-0-	15,600.0	6,240.00	27,510.0	11,004.00	40	45
8/31	Dam - Zone #1	Comp./File/4							(22,400.0)	8,960.00				
8/31	Partial Payment #4		68,100.0	27240.00		-0-		-0-	22,400.0	8,960.00	49,900.0	19,964.00	73	75
9/20	Dam - Zone 1 - (Complete)	Comp. File/4							15,800.0	6,320.00				
9/27	C.M. #7 (Adj. Corr. Yds)	C.M. File			-2,400.0	-960.00	65,700.0	[illegible]	15,800.0	6,320.00	65,700.0	26,280.00		
9/30	Partial Payment #5		68,100.0	27,240.00	-2,400.0	-960.00	65,700.0	26,280.00	15,800.0	6,320.00	65,700.0	26,280.00	100	100
	(Item 4 - 100% Complete	6/30/61)												

4 Item No.

Figure 5-16

SCS-546
(REV. 11-19-64)

BID ITEM RECORD SHEET

Contract No. 12-10-040-226
Structure Pine Crk Diversion

Item No. 5 Unit Price $80.00
Description Class "B" Concrete (Diversion & Hdwrks)
Unit Cu. Yd + 25% 75.63
− 25% 45.38

DATE	DESCRIPTION OF ENTRY	REF. FILE SUPPLEMENT DATA	AUTHORIZED CONTRACT AWARD		AUTHORIZED CHANGE		AUTHORIZED TOTAL		ESTIMATE THIS PERIOD		ESTIMATE COMPLETED TO DATE		% COMPLETE	
1961			QUANTITY	AMOUNT	QUANTITY	AMOUNT	QUANTITY	AMOUNT	QUANTITY	AMOUNT	QUANTITY	AMOUNT	ACT.	SCHED.
5/1	Contract Estimate	Bid Schedule	60.5	4,840.00										
5/31	Cutoff Walls & Floor	Comp. File /5							(22.0)	1760.00				
5/31	Partial Payment #1		60.5	4,840.00		—		—	22.0	1760.00	22.0	1,760.00	36	30
6/20	C.M. #1 Add D.S. Wing Walls (Contract Price)	C.M. File			+ 8.5	+ 680.00	69.0	5,520.00						
6/26	Total Concrete in place	Comp. File /5							45.6	3648.00				
6/30	Partial Payment #2		60.5	4.840.00	+ 8.5	+ 680.00	69.0	5,520.00	45.6	3648.00	67.6	5,408.00	100	90
7/5	C.M #4 - Adj. - Corr. Quant.	C.M. File	60.5	4840.00	- 1.4	-112.00	67.6	5,408.00	—	—	67.6	5,408.00	100	
7/5	Final Status - P.P. #2		60.5	4,840.00	+ 7.1	+ 568.00	67.6	5,408.00	—	—	67.6	5,408.00	100	
	Assume Cement a Separate Bid Item - Unit Price 4.40/bbl - Example Entry													
8/15	Sack Count - 37 each	Inspector's Diary	150.00	660.00					9.25					
8/19	Sack Count - 44 "	"							11.00					
8/24	Sack Count - 58 "	"							14.50					
8/28	Sack Count - 61 " (200)	"							15.25					
8/31	Partial Payment #1		150.00	660.00		—		—	50.00	220.00	50.00	220.00		

5 Item No.

Figure 5-17

Progress Sheet Computations of Contract Pay Items (SCS-536)

General.
Form SCS-536 may be used to summarize quantities of work or materials for pay estimate purposes. (See Figure 5-18).

Quantities recorded on this form should be supported by survey data, computations, invoices and check calculations to ensure that the quantities are correct for the items listed.

The itemized quantities may be used in the preparation of Form SCS-49 and 49a "Contract Pay Estimate."

Preparation of the Form.
Heading.--Location - Location of the field office administering the contract.

Owner - The name of the party or group administering the contract.

Watershed, Sub-Watershed, Site Number and Contract Number - should be shown as they appear in the contract.

Schedule.-Item No. - Record as listed in the bid schedule.

Work or Material - Description of items as shown in the bid schedule.

Date, Name and Quantity - Entries to be made in the appropriate columns by the individuals making and checking the computations.

All bid items should be accounted for each estimate period. When no additional work is accomplished for an item during the period - so state on the report.

Items that are completed during the period should be starred for easy identification.

Include all extra items of work or material that have been added to the contract.

Form SCS-536
MAY 55

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

PROGRESS SHEET COMPUTATIONS OF CONTRACT PAY ITEMS

Location Putnam County, Georgia Owner Luke Dunn

Watershed Rooty Creek Sub-watershed --

Site No. 25 Contract No. 6-GA-SCD-5

Item No.	Work or Material	Computed			Checked		
		Date	Name	Quantity	Date	Name	Quantity
1	Clearing	5/1/63	L.A.H.	11.2	5/4/63	W.J.P.	11.2
2	Clearing and Grubbing						
	Embankment Area	5/1/63	L.A.H.	1.6	5/4/63	W.J.P.	1.6
	Emerg. Spwy. Area	5/1/63	L.A.H.	2.5	5/4/63	W.J.P.	2.5
	Total	5/1/63	L.A.H.	4.1	5/4/63	W.J.P.	4.1
3	Excavation						
	Conduit Strip out	5/1/63	L.A.H.	1919	5/4/63	W.J.P.	1919
	Keyway	5/1/63	L.A.H.	2333	5/4/63	W.J.P.	2333
	Old Channel	5/1/63	L.A.H.	1172	5/4/63	W.J.P.	1172
	Tail Ditch	5/1/63	L.A.H.	196	5/4/63	W.J.P.	196
	Total	5/1/63	L.A.H.	5620	5/4/63	W.J.P.	5620
4	Earth Fill						
	Embankment	5/11/63	L.A.H.	15267	5/11/63	W.J.P.	15267
	Conduit Strip out	--	--	1919	--	--	1919
	Keyway	--	--	2333	--	--	2333
	Old Channel	--	--	1172	--	--	1172
	Total	5/11/63	L.A.H.	20691	5/11/63	W.J.P.	20691
5	Concrete - Class B						
	Riser	--	--	5.47	--	--	5.47
	Anti-Seep Collars	--	--	3.15	--	--	3.15
	Anti-Vortex Baffle	--	--	2.54	--	--	2.54
	Sill	5/11/63	L.A.H.	2.96	5/11/63	W.J.P.	2.96
	Total	5/11/63	L.A.H.	14.12	5/11/63	W.J.P.	14.12
6	Drainage Filter						
	Material	5/5/63		178	5/5/63	W.J.P.	178

Figure 5-18

COMPLETION OF CONTRACT

General.
When final construction operations are complete, or nearing completion, the Government Representative should see that office records are put into shape for closing the contract and filing in the State Office.

All quantities need to be independently checked and field notebooks carefully indexed. The "As Built" set of construction drawings should be carefully reviewed and checked against the engineering notes to verify that all required changes, permanent markers, boundaries, ties or other pertinent data have been accurately recorded. (Refer to "As Built Drawings" write-up in this section.)

It is extremely important that all records and calculations be double checked by separate parties prior to the preparation of the final pay estimates.

The final construction report, when required, and all correspondence and records dealing with the contract should be sent to the State Office within 90 days after completion of the contract. Field office material required to be submitted may include, but is not limited to: working agreement with local organization, contract docket, correspondence, contract modifications, stop and resume work orders, claims for extra work, material certifications, partial and final pay estimates, material test reports, material delivery slips or invoices, field diaries, engineering field note books, "As Built" drawings, and all supporting notes, calculations or forms pertaining to quantities, quality of materials or workmanship.

As Built Drawings

General.
The procedure and requirements for the preparation of as built drawings is outlined in Engineering Memo SCS-17.

This write-up is an excerpt from the memo and may be used to give direction in the preparation of the as built drawings. As built plans for all important structural works of improvement constructed from plans prepared by SCS or its agents shall be maintained in Federal Record Centers. Plans that represent the structure as it was constructed are required, (1) to evaluate the design and operation of the structure, (2) to provide evidence of legal matters, and (3) to facilitate efficient maintenance or reconstruction.

Unless otherwise notified, all watershed structures will be considered important, and the Government Representative shall be responsible to see that one set of the contract plans, (large size, black and white prints) are labeled "As Built" drawings. These drawings will be located in the construction office at the site of the work for recording any significant changes in the drawings.

Changes indicating work as built shall be recorded on the as built prints in red pencil or by other identifiable markings and shall be clear, sharp and neat or shall be drafted on properly identified standard drawing sheets with adequate reference on the new as built drawings and on the as built prints to define the changes made.

A contrasting color, should be used to outline any work that was deleted from the contract.

The details in which specific changes are recorded depends on (1) the effect of the change on the functioning of the structure, and (2) whether or not the change is made on a part of the structure that will remain visible after completion.

Changes in elements of the structure that are visible after construction will not be redrafted. Changes may be shown by red pencil lines, dimensions, angles, stations, notes, etc., on the as built drawings. For example, change in location of emergency spillway of a dam, plot the new location of centerline with new stationing on plan view, show by note that cross sections of channel and proposed structures remain the same. Redrafting of cross sections or structures in the as built location will not be required except for situations that include quantity changes that exceed the 25 percent clause of the contract. For this situation all changes in plan, profile and cross section should be shown on the as built drawings.

Structural or dimensional changes made in any portion of a structure which is not visible; for example drainage systems, cutoffs, principal spillway conduits, pipelines, piling, reinforcing steel or other hidden elements shall be shown in the detail required to provide a complete record.

Each sheet of the original set of drawings and all detail drawings prepared as supplements to the original drawings shall be clearly stamped "As Built."

When construction has been completed all "As Built" drawings and prints shall be carefully checked, reviewing all field notes, diaries and any other records to ascertain that all changes have been properly recorded. These drawings should be transmitted to the State Office with other records of the completed project within 90 days after acceptance of the work.

The following check list is suggestive of changes and additions that should be recorded on the "As Built" drawings.

(1) <u>Permanent monuments.</u>

Show additional permanent points established during construction, include angles or bearing, reference points, stationing, kind of material, and identification.

(2) <u>Bench marks - Permanent.</u>

New - show location, elevation, description and identification.

Old - corrections - (elevation, location or description).

(3) <u>Monuments or B. M.'s - Not Shown on the Drawings.</u>

Identify - show old location, disposition (new location, references, elevations.)

(4) <u>Utilities.</u>

Unknown - identify by name, location, owner, kind of material, size, show disposition.

Known - show any changes in location, owner, kind of material or size.

(5) <u>Base Lines or Centerline Used for Control.</u>

Show changes in location, stationing, references to old line, equations, bearings or angles.

(6) <u>Structures.</u>

Show all changes in: location, design, dimension, kind of materials, additions or deletions.

Include complete detail drawings for additional structures or major changes in existing structures.

(7) Right-of-Way and Easements.

Show changes in right-of-way or easement limits, properly identified, that were made a matter of record subsequent to the preparation of the construction drawings.

Construction Completion Report

General.
The preparation of a completion report covering the highlights of the construction operations and the contract administration for a project is optional.

The desirability and advantages that may be derived from such a report should be seriously considered by the state staff. At the time of completion of the contract while all the pertinent facts and data are readily available, it may appear to be an unjustifiable effort of little or no merit. In subsequent years when all the records have been removed from the local files and the personnel who had intimate knowledge of the construction are not readily available, it is conceivable that questions may arise within our Service or in our contacts with local people that could be simply resolved by reference to a properly documented final construction report.

It is intended that when the report is prepared that it will be concise and will represent the thinking of the construction force, revealing the problems during construction, their impressions of the contractor, and his operations, and the effectiveness and quality of the completed project.

The contents of the report will necessarily have to vary, depending on the type and magnitude of the work.

Report Outline.
The following outline may be used to give guidance in the preparation of the report:

(1) Brief description of project - scope, location, purpose, cooperating agencies. Give names: Contracting Officer, Local Organization Board members ---.

(2) Dates and Facts

(a) Number of bidders

(b) Date of award

(c) Name, address of contractor, also subcontractors.

(d) Dates and reasons for major shutdowns required for the contract.

(e) Revisions of contract time - amount, days of liquidated damage.

(f) Date of formal acceptance.

(3) Installation Services

(a) Indicate who was responsible for engineering and inspection (Service or others).

(b) List names, titles and duties, personnel assigned to project.

(c) Comment on adequacy of engineering force--make suggestions for improvement of organization.

(4) Installation

(a) Types of equipment and methods used for major items of work.

(b) Comment on new or special types of equipment or techniques - adaptability for other types of work.

(c) Production rates - comment on exceptionally high or low rates of production, indicate average production rates per hour or day for the larger quantity items.

(5) Problems

(a) Site or material conditions which varied from design or plan - how was problem resolved.

(b) Quality of materials or workmanship.

(c) Completeness and accuracy of specifications and drawings - be specific as to omissions, errors, or weak points. Make suggestions for improvement.

(d) Any other situations - weather, labor, relations with local organization or public, that were unusual or affected operations.

(6) Materials

List manufacturers producing major items incorporated in the project: concrete products, metal, fabricated assemblies, etc. Comment on quality and workmanship, also discuss any problems on earthwork, borrow, rock riprap or other major items of work.

(7) Evaluation of Contractor's Performance

(a) Experience

(b) Equipment

(c) Financial problems

(d) Integrity

(e) Organization and supervision

(f) Production and quality of finished product

(g) Attitude and relations:

1. General public

2. Local contracting organization

3. Engineering installation force - comment on contractor or his substitute's willingness to comply with instruction or orders.

(h) Rating

Make recommendation as to desirability of awarding future contracts. (If unfavorable, give reasons or examples to support your decision.)

(8) <u>Modification and claims</u>

Comment on contract modifications.

Negotiations of prices, extras, claims, liquidated damages or other items that changed the value of the contract.

Reasons for, and suggestions how they might have been avoided.

(9) <u>Costs</u>

Report original and final value of contract, and percentage of over-run or under-run. Also show original and final costs to the Government and the local Contracting Organization.

(10) <u>Pictures</u>

Include photographs, if available, to show major construction operations and finished project. Include foundations, latent conditions, special equipment and unusual methods. Select pictures carefully to present the intended information. Keep the number of views to a minimum to show only the highlights, and scope of the project.

The following printed form type of completion report, see Figures 5-19, 5-20 and 5-21, may be used in lieu of a narrative. Any unusual features including changes or additions, when thought of significant importance should be written up as a supplement. The report may also include a limited number of well captioned photographs to show construction features and scope of the project.

Distribution

Distribution of the completion report within the state will be as directed by the State Conservationist.

One copy may be forwarded to the Engineering and Watershed Planning Unit (optional states and unit).

SCS-547A
(Rev. 11-19-64)

CONSTRUCTION COMPLETION REPORT

To: ______________________________ Date ________________________
Contracting Officer

____
Town State

1. Contract No. ____________ for construction of ______________
Site Nos. ________________, ____________ Tributary Watershed
____________________ River Watershed, State of _______________

INFORMATION RELATIVE TO CONTRACT

2. Name of Contractor
3. Address of Contractor

4. Original Amount of Contract
5. Revised Amount of Contract

6. Location of Work
Site No. ___ is approximately ___ miles ___ of ____________
on the __________________ farm ____________________
Site No. ___ is approximately ___ miles ___ of ____________
on the __________________ farm ____________________

7. Description of Work
____
____
____
____
____
____
____
complete in accordance with contract specifications and drawings together with such additional work as required or ordered in writing by the Contracting Officer.

8. Dates
Contract Date ______________ Original Date for Completion ______
Notice to Proceed __________ Revised Date for Completion ______
Work Started _______________ Work Completed __________________

9. Time allowed for completion: ____ calendar days after receipt of notice to proceed. Extended _____ calendar days by Modifications Nos. ____________________

10. Liquidated Damages: Contract provided that $__________ per calendar day would be assessed for each day of delay. No. of days charged ________________

11. Plans and Specifications:
The following plans and specifications were used:
Site No. _______ Dwgs. Nos. ___________ thru __________
Site No. _______ Dwgs. Nos. ___________ thru __________
Site No. _______ Dwgs. Nos. ___________ thru __________
Site No. _______ Dwgs. Nos. ___________ thru __________

Figure 5-19

SCS-547B
(Rev. 11-19-64)

CONSTRUCTION COMPLETION REPORT (Cont.)

12. Contractor Performance Rating:

Performance Chart (check below)

Factors Considered	Excellent	Above Average	Average	Satis-factory	Unsatis-factory
Success in meeting scheduled completion dates					
Quality of work performed					
Organizational ability and efficiency					
Cooperative attitude of contractor					
Cooperative attitude of Sup'ts and Foremen					
Effectiveness of supervision (Contractor's)					
Effective use of equipment and manpower					
Adherence to safety regulations					

Overall adjective rating to be entered in appropriate space below and signed by the rating and reviewing officials

Rating Official	Reviewing Official
Rating__________	Rating__________
Signature__________	Signature__________
Govt. Representative	Title__________

13. Give a brief summary of major points concerning the contract, such as weather conditions, labor problems, material shortages, etc.

____

____

____

____

____

____

____

14. Final inspection made on __________ by ________________
Date

_______________, _______________ and _______________

15. Report prepared:	Approval Recommended:
By__________	By__________
Title__________	Government Representative
Date__________	Date__________
	Approved:
	By__________
	State Conservation Engineer
	Date__________

Figure 5-19 (Cont.)

SCS-548
(Rev. 11-19-64)

U. S. DEPARTMENT OF AGRICULTURE
Soil Conservation Service

SUMMARY OF
CONSTRUCTION QUANTITIES AND COSTS
FOR

Site No. ______ **Watershed** ____________________ **Contract No.** ____________ **Contractor** ____________________

Item No.	Item Description	Total Quantity		Unit	Unit Price	Total Amount		Modification	
		Original	Revised			Original	Revised or Final	Number	Date

Totals for Site No. ___ $ __________ $ __________
Net (Decrease)(Increase) $ __________
Total for Contract (Decrease)(Increase) $ __________

Figure 5-20

Table of Forms Used by Field Construction Office

General.

Prior to starting a new construction contract, it is desirable for the Government Representative to consult with the State Engineering and Administrative Divisions and determine what record and report forms will be required, the distribution and number of copies, and the due date for each report.

Similar procedural methods should also be determined in advance in conjunction with A & E engineering firms or Local Organization engineers responsible for installation services.

Figure 5-21 illustrates a form that may be prepared to record the required forms and also serve as a reminder to the responsible parties for timely preparation of the required records or reports for the project.

Preparation of the Form.

Form No.--List correct prefix letters and number for each form.

Title of form.--Enter opposite form number, the correct title or heading as it appears on the form.

Offices - No. of copies.--Indicate under each applicable separate heading the number of copies required by use of figures or check mark. The letter O may be entered as a suffix to indicate distribution of original copy, or letter S for distribution of signed copies.

Due date.--Indicate completion date for office file, or date for mailing to receiving office.

Distribution.

The number of copies and the need for this form will be as determined by the state office. It is anticipated that the use of this form would be restricted primarily to the project office, and referred to by personnel who have responsibility for the preparation of the required reports or records.

SCS-549
(REV. 11-19-64)

TABLE OF FORMS USED BY FIELD CONSTRUCTION OFFICE

(Distribution - Number Copies)

Form No.	Title of Form	Offices						Contract Local Organ.	Contractor	Due Date or Frequency
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Figure 5-21

NATIONAL ENGINEERING HANDBOOK

SECTION 19

CONSTRUCTION

CHAPTER 6. TECHNICAL REFERENCES

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* Concrete Manual, U.S.D.I., Bureau of Reclamation, 7th Edition, 1963, Supt. of Documents, G.P.O., Washington 25, D. C.

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S.C.S. Publications

* Standard Specifications - Construction and Construction Materials, SCS, Washington, D. C., 1958.

* Administrative Services Handbook, Section 280, SCS, Washington, D. C. 1958.

* Watershed Protection Handbook, SCS, Washington, D. C.

Engineering Handbook (Applicable Sections), SCS, Washington, D. C.

* - Indicates reference material that should be available in each construction office.

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